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CONTENTS

ON-FARM MECHANIZATION OF PADDY IN THE PHILIPPINES

Hernaiz G. Malanon[1] and Renita SM. Dela Cruz[2]

ABSTRACT

The paper provided information on the status of on-farm paddy mechanization in the Philippines as bases of formulating appropriate mechanization strategies and as baseline information for future evaluation of existing mechanization programs. Employing one shot cross-section survey designed interviews of rice farmers were carried out in major rice production areas of the country. The survey covered 1,235 rice farmers in 13 rice-producing provinces in 2012-2013.

Results showed that rice farm operations such as threshing and land preparation were already highly mechanized with 93% of paddy volume passing through mechanical threshers and 79% of areas being serviced by machines. Land preparation activities such as planting, fertilizer application, dike repair/clearing and spraying were still done predominantly using manual power.

The power utilized in land preparation was 61% of the total power utilized from land preparation to threshing of palay, followed by the power utilized in threshing (24%), harvesting (7%), and transplanting and crop management (2%). The high power required in land preparation and threshing was a major reason for the higher preference of rice farmers to own and/or operate hand tractors and threshers as 52 and 25% of them owned and operated hand tractors and mechanical threshers, respectively. Several recommendations were forwarded to guide program planners and implementers in crafting regional mechanization plans.

Keywords: Agricultural machinery, Degree of mechanization, Draft animals, Power utilization, Rice mechanization, Threshing

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INTRODUCTION

The Philippines needs to accelerate agricultural mechanization as a means to attain food sufficiency, increase farm income and modernize agriculture. This is embodied in the Philippine Agriculture and Fishery Mechanization Act framework, intensified with the implementation of Farm Mechanization Program which is a major component of the Food Staples Sufficiency Program and further reinforced with the enactment of R.A. 10601 or AFMech Law.

To achieve these goals, one of the strategies adopted is to unify R&D efforts and strengthen technology transfer to farmers through the conduct of updated and comprehensive review of the status of mechanization. An assessment of machines suitable to farmers and their farm conditions was also considered necessary. This requires deeper and broader understanding on the multi-faceted aspects of farming as mechanization impinge on the specific characteristics of the farmers as well as the agro-ecological, socioeconomic and technical conditions inherent in each specific locality. This study is important in the formulation of location-specific recommendations for appropriate mechanization strategies. It also provides baseline information for future evaluation of various mechanization programs.

In 1990, the Philippines ranked 9th among the 12 Asian countries in terms of agricultural mechanization level with 0.52 hp ha^{-1} while countries such as Japan and Korea already posted 7.00 and 4.11 hp ha^{-1}, respectively.

The level of mechanization of the Philippines was slightly higher than Indonesia (0.41 hp ha^{-1} but slightly lower than Thailand (.79 hp ha^{-1}). The level of mechanization was updated by Rodulfo et al. (1998) and reported that mechanization level for rice and corn farms in the Philippines was 1.68 hp ha^{-1}.

In a provincial-wide assessment of mechanization, Bermudez et al. (2004) found that there was a 2.6 hp ha^{-1} average level of mechanization in Nueva Ecija, the province considered to be the rice granary of the Philippines.

In terms of the power source, only 0.1% is coming from manually operated equipment, 7% from draft animals and 92.9% from engine power.

A more recent assessment of Dela Cruz and Bobier (2012), established the available farm power that could be utilized in Philippine agriculture by using the inventory of machines conducted by PHilMech and information from the Bureau of Customs and importer-dealers of machines as well as the databases of other national and local government units. The study identified that as of 2011, the status of farm power for utilization in Philippine agriculture was 1.23 hp ha-1, the bulk of which was supplied by mechanical power (75%). The authors further concluded that the available farm power coming from mechanical, draft animals and human power, was concentrated in rice and corn production operations and that mechanical power available for on-farm utilization on postharvest operations significantly lagged behind the power available for production operations.

Since the machines were concentrated in the production of rice and corn, and excluding the machines that were particularly used in other crops like sugarcane, the level of farm power available for rice and corn was estimated at 2.31 hp ha-1, with 77% of the power available from machines, and 17 and 6% from draft animals and human power, respectively.

The level of mechanization in terms of hp ha-1 is a quick index of mechanization but lacks the details of whether the available power is utilized and on what specific crops and operations are machines utilized. The index also assumes that all the areas for agriculture have the same level of mechanization which is not really the case because machines have specific applications in terms of crops and operations to be accomplished and that the machines are not distributed equally in the areas where there is actual production of crops. It is therefore imperative to evaluate the status of mechanization of specific crops like rice.

This study generally aimed to assess the state of agricultural mechanization of rice farms in the Philippines.

METHODOLOGY

The study used a one shot cross-sectional research design involving 13 rice-producing regions in the Philippines. The total respondents of 1,235 rice farmers were determined by applying the Slovin's formula, using a 3% margin of error. The respondents were selected using multi-stage sampling. The first stage involved the selection of sample province from the region followed by the selection of sample municipalities from each province. The study limited the sampling frame on the key grain areas identified by the Department of Agriculture on the premise that government efforts on mechanization are concentrated on these areas. Majority of the selected provinces representing each of the 13 regions, comprised at least 40% of the total regional physical area planted to rice. After the selection of sample provinces, representative municipalities from each provincial districts were chosen based on the provincial average crop yield. The sample size for each municipality was determined using proportional allocation and the sample respondents were selected at random. The provinces covered were: Pangasinan, Isabela, Kalinga, Nueva Ecija, Oriental Mindoro, Camarines Sur, Iloilo, Bohol, Leyte, Bukidnon, Davao del Norte, South Cotabato, and Agusan del Sur.

Data were primarily collected through personal interviews using structured questionnaire. The survey covered farmers' operations for the previous two cropping seasons to cover wet and dry seasons of CY 2012-2013. Pre-testing of survey instruments was done to determine the effectiveness and ascertain the reliability and validity of the questionnaires. . Key informant interviews, actual field observations and secondary data collections were also done to supplement gathered information and gain deeper knowledge on the details of issues surrounding agricultural mechanization. Key informants included staff from the Regional Field Units-RAEG and Rice/Corn Coordinators, Provincial Agriculture Offices, Municipal Agriculture Offices and other entities involved in agricultural mechanization.

Descriptive statistics such as percentages, frequency distribution, cross tabulations and measures of central tendency were used in analyzing the information gathered applying the Statistical Package for Social Sciences (SPSS). Computations of the different indicators of level of mechanization were done using the following equations which were adopted from the methods utilized by the Agricultural Machinery Development Program, University of the Philippines Los Baños (UPLB):

Percent area mechanized:
[area mechanized (ha)/ total area] x 100 (1)

This refers to the portion of the respondents' total farm area that was accomplished or completed by using mechanical power.

Percent farmer-user:
[(number of user of a specific machine)/total number of respondents)] x 100 (2)

This refers to whether the farmer-respondent uses machines (e.g., tractor, pump set, thresher, etc.)

Level of power utilized:
nominal power of engine used (hp) x efficiency factor x number of units x number of hours used per ha (3)

This refers to the total hp-hr a^{-1} utilized from three sources of power; human, man-animal and man-machine for all on-farm operations. The specific nominal horsepower values utilized by the respondents were adjusted for standard efficiency values. These efficiency values were established by Agricultural Machinery Testing and Evaluation Center (AMTEC) and are considered standard values for the country. These are:

Effe = Prime mover efficiency at 0.80
Efft = Transmission efficiency at 0.80
Effb = Belt efficiency at 0.95
EffPTO = PTO efficiency at 0.90
Effdb = Drawbar efficiency at 0.75

Effe ; Efft and Effb were used for machines such as hand tractor (all types), combine harvester, reaper, pump set, thresher and sheller while Effe; Efft; EffPTO or Effdb were applied for four-wheel tractors, depending on the attached implement.

In the case of manual horsepower or power derived from manual labor, standard horsepower values were 0.10 hp for males and 0.075 hp for females. In the case of draft animals, standard horsepower value was 1.0 hp (based on UPLB College of Agriculture, Dept. of Animal Science study).

Ownership of draft animal:
(no. of farmers with draft animal/total no. of respondents) x 100 (4)

This refers to whether the farmer-respondent owns draft animals (carabao, cattle or horse).

Ownership of engine-powered machine:
(No. of farmers with specific machine/total number of respondents) x 100 (5)

This refers to whether the farmer-respondent owns a specific machine (e.g., hand tractor, pump set, thresher, etc.)

RESULTS AND DISCUSSION

Rice Area Mechanized

Among the major farm operations in the production of dried threshed paddy, land preparation and threshing could already be considered highly mechanized with 79% of the land area of the rice farmers already prepared using mechanical power while 93% of their total volume of paddy harvested was already threshed also by mechanical power (Table 1).

Tillage operations which includes plowing and harrowing were already highly mechanized across all study areas, notably Nueva Ecija, Isabela and Pangasinan. More than 90% of the rice areas of the farmers surveyed was cultivated using mechanical power. Other provinces that reported high extent of mechanization were Iloilo, Kalinga, Leyte and South Cotabato, with mechanization degree higher than 80%. Meanwhile, the lowest mechanization degree was recorded in Agusan del Sur (55%) and Oriental Mindoro (59%) implying that support of appropriate machines for land preparation is relatively more needed in these provinces and other areas similarly situated.

For operations such as planting, weeding and spraying, all farms still used manual power except in the areas of Isabela, Pangasinan, Mindoro Oriental and Kalinga where mechanical harvesting has become popular with the introduction of combine harvester. The number of combine harvester has been continuously spreading in different parts of the country where capable farmers are being encouraged to engage in custom service provision for additional and higher profits.

Threshing operation had the highest mechanization degree in all the provinces. This was mostly noted in Pangasinan, Isabela, Mindoro Oriental, Davao del Norte, Nueva Ecija, South Cotabato, Iloilo, Kalinga, Agusan del Sur and Camarines Sur where 90 or more than 90% of the total volume threshed was done using motorized threshers. The provinces of Bohol and Bukidnon had less than 90% of their harvest threshed with mechanical power.

Mechanical threshers had earlier been introduced in farmers' farms because of the drudgery of threshing operation, inadequacy of labor and timeliness factor (Bautista, 2003). The equipment had been common farm equipment not only in rice but also in corn farms.

Five among the sample provinces (Iloilo, Bohol, Camarines Sur and Pangasinan) utilized mechanical dryers in drying. The highest percentage volume of paddy dried using mechanical dryers was observed in Iloilo with 11% followed by Leyte at 7% while the rest had 0-3%.

Table 1. Percent of paddy area/volume mechanized, selected rice producing provinces in the Philippines, % reporting, 2012-2013

	Operation				
Province	**Land Preparation**[1]	**Crop Est./ Care**[2]	**Harvesting**	**Threshing**[3]	**Drying**[3]
Pangasinan	92	0	17	99	2
Isabela	95	0	17	99	0
Nueva Ecija	98	0	1	98	2
Mindoro Oriental	59	0	16	99	0
Cam. Sur	71	0	0	90	3
Kalinga	87	0	5	94	0
Iloilo	89	0	0	95	11
Bohol	74	0	0	76	0
Leyte	88	0	0	92	7
Bukidnon	65	0	0	86	0
Davao del Norte	74	0	0	99	0
South Cotabato	81	0	0	97	0
Agusan del Sur	55	0	0	93	0
All	*79*	*0*	*4*	*93*	*2*

[1] Plowing and harrowing, including preparation of seedbed; [2] Seedling preparation activities, planting, fertilizer application, weeding and spraying; [3] Percent volume

Ownership of Farm Animals and Machine Implements

Table 2 shows the ownership of draft animals and farm equipment by rice farmers in 13 sample provinces. The average percentage of farmers owning draft animals was 14% ranging from 6-26% with Nueva Ecija and Iloilo having the least and Bukidnon having the highest. Relatively, higher percentage of farmers from the provinces of Mindanao owned draft animals.

Few rice farmers still maintain draft animals to perform plowing and harrowing. Those with farms that are not suitable for mechanization because of topographical constraints, like small-sized fragmented terraced farms used draft animals. In addition, farms cultivated using machines still required plowing of corners and fields harrowed by means of floating tillers need leveling which is mostly done using animal-drawn plank. Other farm activities that still utilize draft animals were seedbed preparation and hauling.

For all provinces, 52% of the respondents own hand tractors that were mostly utilized in plowing and harrowing operations. The high ownership of hand tractors was attributable to the relative affordability of the machine, versatility in terms of uses and the constrained land preparation calendar. Farmers had to keep up with the irrigation calendar and schedule of other neighboring farms. This was even more problematic for interior farms with no separate road to access farms. They could not afford to allow other farms to finish their activities, as they will encounter difficulty in getting into their own farms. The high degree of ownership of the locally developed and manufactured handtractors and threshers proved the relevance of these machines to the actual needs of the rice farmers.

High ownership of irrigation pumps were recorded in provinces that are known to be the highest producing areas in their respective regions like Pangasinan, Isabela, Camarines Sur, Nueva Ecija and Iloilo. The provinces of Pangasinan and Iloilo had irrigated areas of 67 and 43%, respectively and the other three provinces had irrigation rates above 70%, with Isabela even higher at 90% (BAS, 2014).

It was evident that even in areas with more extensive irrigation systems, some farms were not completely served or were not receiving water on time. Farmers had to use pumps to supplement water from irrigation systems so that they can plant on time, such as in the preparation of seedbed for rice seedlings. Rice seedlings had to be prepared ahead of the actual release of irrigation water.

In the other study areas, very few irrigation pumps were noted while the rest had no irrigation pumps. Among others, the absence or low percentage ownership of irrigation pump could be due to the presence of enough water to sustain rice crop as in Agusan Sur, Bohol, some parts of South Cotabato and Bukidnon which have Type IV climate (rainfall more or less evenly distributed throughout the year).

Twenty five percent (25%) of the farmer-respondents in the study areas own rice threshers. Compared to hand tractors that were also used for hauling and as means of transport for farmers, rice thresher is exclusively used for threshing paddy.

In addition, rice thresher had higher field capacity than hand tractor so there was lesser quantity of rice threshers, given the same service area. For a given area, a hand tractor was used several times in subsequent plowing, harrowing and levelling operations. Areas such as Oriental Mindoro, Iloilo and Camarines Sur had relatively higher ownership of rice threshers while farmers in Bohol, Pangasinan and South Cotabato had low ownership.

Types of Machines Utilized by Rice Farmers

For rice farmers who used mechanical power in plowing, majority employed hand tractors or power tillers (Table 3). Hand tractors were primarily used in all provinces although several farmers in Pangasinan, Nueva Ecija, Mindoro Oriental, South Cotabato and Agusan del Sur also utilized medium four-wheel tractors in plowing operation. Floating-type power tillers also known as "mudboats", "bao bao" or "turtle" were commonly used in the Visayas and Mindanao areas and part of Camarines Sur while hand tractors often called "kuliglig", popularly used in Luzon were also observed in South Cotabato.

Table 2. Ownership of draft animals and farm machinery, rice-producing provinces, % reporting, 2012-2013

	Ownership of Draft Animals and Farm Machines (% Reporting)			
Province	**Draft Animal**	**Hand Tractor***	**Irrigation Pump**	**Rice Thresher**
Pangasinan	8	58	29	14
Isabela	17	84	20	29
Nueva Ecija	6	52	15	17
Mindoro Or.	20	69	-	48
Cam. Sur	9	58	18	38
Kalinga	11	80	3	23
Iloilo	6	68	15	39
Bohol	21	33	1	6
Leyte	11	42	6	17
Bukidnon	26	23	1	24
Davao Norte	20	33	7	22
Cotabato So.	12	31	-	15
Agusan Sur	18	50	1	27
All	*14*	*52*	*9*	*25*

** Includes floating type tillers predominantly used in the Visayas/Mindanao areas and parts of Luzon*

In the case of harrowing operation, more farmers used hand tractors primarily because this is the most prevalent machine in the area which is available for rent. Farmers also recognized the disadvantage of using large four-wheel tractors in terms of breaking down soil structure.

During the time of interview, all the farmers who mechanized reaping in Pangasinan and Nueva Ecija used motorized reapers with engine power rating of 4-hp. In Isabela, 90% of the rice farmers who applied mechanical power in harvesting already utilized combine harvesters with 60 or 70-hp ratings. Meanwhile, all the farmers who mechanized harvest in Mindoro employed combine harvesters. The preference for larger capacity combine harvester could be due to the relatively larger paddy areas owned by individual farmers in the province (Malanon et al. 2014).

For mechanized threshing, farmers in all areas primarily used axial flow threshers powered by gasoline or diesel engines. Diesel engines were commonly used in Camarines Sur, Bohol and Bukidnon. These types of engines were also used as prime movers of power tillers.

Power Utilization in Rice Farms

The power utilized in land preparation (plowing and harrowing) was the highest, accounting for 61% of the total power utilized from land preparation to threshing (Table 4). About one fourth (24%) of the total power was utilized for threshing operations. Land preparation and threshing were the two major operations cited by Bautista (2003) to be highly mechanized because they are the operations that require the highest power to accomplish. Harvesting (cutting and gathering or piling) was the third highest operation requiring 7% of the total power. Following the transplanting method, planting (6%) came next to harvesting in terms of power requirement.

The variations in power utilization of the sample provinces were due to the different combinations of manual, man-animal, man-machine systems employed by farmers, the capacity of engines used and the frequency of application.

Table 3. Types of machines used by rice farmers in mechanizing land preparation and harvesting operations, % reporting, 2012-2013

	Plowing		Harrowing		Harvesting	
Province	**Hand Tractor**	**4-W Tractor**	**Hand Tractor**	**4-W Tractor**	**Combine**	**Reaper**
Pangasinan	65	35	96	4	-	100
Isabela	100	-	100	-	90	10
Nueva Ecija	70	30	97	3	-	100
Mindoro Or.	96	4	97	3	100	-
Cam. Sur	100	-	100	-	-	-
Kalinga	100	-	100	-	33	67
Iloilo	99	1	99	-	-	-
Bohol	100	-	100	-	-	-
Leyte	100	-	100	-	-	-
Bukidnon	100	-	100	-	-	-
Davao Norte	100	-	100	-	-	-
South Cotabato	97	3	100	-	-	-
Agusan Sur	97	3	100	-	-	-
All	*94*	*6*	*99*	*<1*		

Some farmers did multiple operations of land preparation activities such as plowing and harrowing, spraying, weeding and fertilizer application. For tillage operations, multiple applications of farm power were generally practiced by farmers who have their own facilities. It was also required in farms with tough soil and necessary for rarely cultivated farms.

For other activities such as spraying and fertilizer application, the frequency of application depended on the sufficiency or quantity of farm inputs, degree of pest incidence and soil fertility. While high power usage may imply additional cost or inefficiency, power utilization was associated with higher productivity as areas with higher yields reported higher power utilization.

The power utilized from land preparation to threshing, following the transplanting method was 175.69 hp-hr $ha^{-1}season^{-1}$. Power utilization was highest in Isabela (215.28 hp-hr ha^{-1}), Pangasinan (198.62 hp-hr ha^{-1}), Nueva Ecija (196.50 hp-hr ha^{-1}) and Kalinga (181.09 hp-hra^{-1}).

Expectedly, utilization of power was lower in farms practicing direct-seeding. While 10.34 hp-hr ha-1 was utilized in the transplanting method, only 11% of this energy (1.15 hp-hr ha-1) was used for direct seeding.

The lowest power utilized in producing threshed dried paddy was recorded in Agusan del Sur at 145.33 hp -hr ha-1 for farms that practiced transplanting and 137.16 hp-hr ha-1 for farms that adopted direct seeding method.

Generally, the level of power utilized in the provinces of Visayas and Mindanao islands was relatively lower compared to Luzon as the power ratings of most engines used were generally lower in addition to the fewer number of mechanical power available. This finding corroborates the result on level of farm power available for mechanization which was found to be 1.76, 0.95 and 0.91 hp/ha for Luzon, Visayas and Mindanao, respectively (Dela Cruz and Bobier, 2013).

Table 4. Power utilized per season in production and postproduction operations, rice production areas, 13 major rice-producing provinces in the Philippines, (weighted hp-hr ha-1 season-1), 2012-2013

		Planting					**Total**	
Province	**Land Prep.**	**Trans-planted**	**Direct Seeded**	**Crop Care**	**Harvesting**	**Threshing**	**Transplanted**	**Direct Seeding**
Pangasinan	128.78	11.45	1.37	3.87	10.83	43.69	198.62	188.54
Isabela	135.42	11.31	0.81	3.95	20.77	43.83	215.28	204.78
Nueva Ecija	126.73	10.17	1.96	4.18	9.77	45.65	196.50	188.29
Or. Mindoro	87.06	10.36	1.60	6.10	20.70	43.35	167.57	158.81
Cam. Sur	81.73	9.76	0.83	4.85	10.66	44.91	151.91	142.98
Kalinga	106.61	12.34	1.09	4.04	13.07	45.03	181.09	169.84
Iloilo	113.84	11.94	1.03	4.51	11.75	37.66	179.70	168.79
Bohol	99.28	8.55	1.40	5.20	8.72	41.92	163.67	156.52
Leyte	108.55	8.00	-	4.54	10.97	45.31	177.37	-
Bukidnon	98.39	10.07	1.30	3.06	11.02	39.26	161.80	153.03
Davao Norte	105.55	10.74	0.58	3.58	11.75	40.19	171.81	161.65
South Cotabato	111.99	10.82	1.04	2.62	10.76	37.21	173.40	163.62
Agusan del Sur	83.75	8.93	0.76	3.66	10.98	38.01	145.33	137.16
All	106.74	10.34	1.15	4.17	12.44	42.00	175.69	166.50
% of total based on transplanting method	61	6	-	2	7	24	100	-

The relatively lower farm power available in Visayas and Mindanao limits power utilization. The results also suggested that rice farms in Visayas and Mindanao should get higher prioritization in terms of giving out support for the acquisition of appropriate machine technology.

Figure 1 shows the relative distribution of power utilization in producing threshed dried paddy. Power utilized was highest in plowing and harrowing accounting for 32 and 29 % of the total power, respectively, while manual activities such as weeding and spraying registered the lowest.

The third highest power utilization was observed in threshing as almost all farmers used mechanized threshers, with some farmers in three major producing provinces already using power-intensive combine harvesters as of the time of the study. Threshing operation even with mechanical thresher, required several persons to perform.

These included several laborers to convey the harvested rice panicles into the thresher's feeding board, feed the rice panicles into the threshing cylinder, adjust the blower and tend the oscillating sieve, bag and pile the threshed paddy. Other farm activities with minimal utilization of power were spraying, fertilizer application and weeding. These activities had been done solely by human power and with minimal manpower requirement.

CONCLUSION AND RECOMMENDATION

In rice production, operations such as land preparation and threshing were already highly mechanized although few areas reported lower mechanization degrees. In terms of operations with high potential for mechanization, harvesting and planting were the two next labor intensive farm operations that are expected to be affected by the diminishing local labor due to ageing of farmers and urban migration or lack of interest of the youth in farming.

Mechanized harvesting using combine harvesters had been gaining popularity in some parts of the country such as Isabela, Oriental Mindoro, Nueva Ecija and Kalinga. This is due to benefits derived from the technology, by both the users and service providers (Dela Cruz and Bobier, 2013).

There is a need to inform or educate the farmers about the advantages of mechanization and availability of mechanization technologies. Farmers need to know that there are available technologies and the subsequent advantages and/or benefits that could be derived from their use in order to stimulate demand.

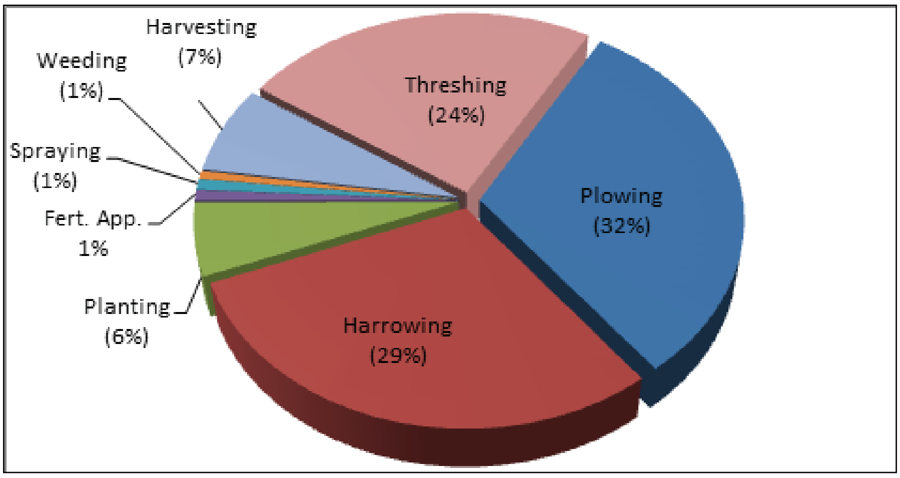

Figure 1. Percentage distribution of power utilized by rice farmers from land preparation to threshing, 13 rice-producing provinces in the Philippines, 2012-2013

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EFFECT OF ETHANOL VAPOR ON THE QUALITY OF BROCCOLI

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ABSTRACT

The efficacy of ethanol vapor in extending the shelf-life and in maintaining the overall quality of broccoli in storage was conducted for 10 days. A factorial experiment involving 2 kg of broccoli heads was treated with 5% ethanol and packed in oriented polypropylene bag (1040x1080mm, thickness 30 μm) with two holes (5mm diam) on both sides. Broccoli samples were treated with ethanol vapor by placing together inside the package a pack of 100 ml food grade ethanol encapsulated into 200g of silica gel. Treated and untreated broccoli heads were stored at laboratory condition with 2 different storage conditions (17±0.3 and 22±0.2 0C). Destructive sampling was carried out at 0, 3, 5, 7 and 10 days after storage. Samples from each storage conditions were analyzed for biochemical changes like chlorophyll degradation, total soluble solid content, nutritional quality, weight loss and organoleptic quality.

Results showed that broccoli treated with 5% ethanol vapor has lower total chlorophyll content loss than that of untreated samples. Weight loss was within the minimum acceptable level of 4%, the treatment also retained high level of ß-carotene, and total phenolic and ascorbic acid content and delayed the development of decay until seven days in storage. Ethanol vapor could extend the shelf-life of broccoli by five and seven days at 22±0.2 0C and 17±0.3 0C storage temperature, respectively.

Keywords: Climacteric, Ethanol Vapor, Ethylene Production and Respiration

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INTRODUCTION

Broccoli (Brassica oleracea) is one of the most popular but highly perishable vegetable and is an important source of vitamins, minerals and antioxidants which are essential components of the human diet. It ranks fifth among fresh fruit and vegetable with substantial amount of vitamin C content (Salunkhe et al. 1976). However, broccoli senesces rapidly after harvest, the florets turning yellow in three to four days at storage without postharvest treatment. Development of off-odor and incidence of decay are expected at storage in room temperature after harvest. Broccoli is considered highly perishable because of its short shelf-life. Thus, appropriate treatment is necessary to maintain the overall quality of broccoli until it reaches the consumer for consumption.

Broccoli is generally handled and distributed at low temperature. Methods to inhibit or delay ripening have been investigated by several researchers including modified atmosphere (Ballantyne et al. 1988), controlled atmosphere (Hansen et al. 2001), 1-methylcyclopropene treatment (Ku and Wills, 1999) and high temperature treatment (Terai et al. 1999). All of these studies have promising effectiveness in delaying the rapid senescence of broccoli. However, most of these studies are very expensive because of the equipment needed during postharvest treatment.

Ethanol vapour treatment has also been studied and found effective in inhibiting the rapid senescence of a number of climacteric fruits and vegetables including broccoli. Dela Cruz et al. (2012) found ethanol vapor effective in prolonging the shelf-life of broccoli at laboratory scale experiment. Ethanol vapor inhibited the rapid degradation of chlorophyll a and b content up to 10 days in storage. Weight loss of ethanol vapour treated broccoli was within the minimum acceptable limit of 4 % after five days in storage.

Ethanol vapor inhibited the rapid manifestation and development of bacterial soft rot and mold infection during storage, thus maintaining the acceptable visual quality up to seven days in storage. These results agreed with the findings of Zusuki et al. (2004) where the yellowing of broccoli was inhibited over five days in storage compared to untreated broccoli.

In consideration of the practical application of the findings, the current study was conducted to determine the effect of ethanol vapor on bigger volume-samples and to investigate further, the effect of ethanol vapor on broccoli qualities such as the retention of important nutrient, and the organoleptic and sensory quality after ethanol vapor treatment.

METHODOLOGY

Encapsulation of Ethanol into Silica Gel and Packaging

Dry silica gel (5-10 mesh) weighing 200 g were placed in 500 ml capacity airtight jar. 100 ml food grade ethanol was encapsulated by directly incorporating the ethanol into silica contained in jar and then immediately covered with screw cap to allow the silica to absorb the liquid ethanol. Immediately after encapsulation, silica gel were packed first in permeable paper (6.5 x 15.5cm) and sealed with second layer of non-permeable plastic film (oriented polypropylene/cast polypropylene with 60 um thickness).

Ethanol Vapor Treatment and Storage of Broccoli

Stems of newly harvested mature broccoli (Brassica oleracea L.) cv. Legacy were surface sterilized by dipping in 70% food grade ethanol for 60 seconds and then rinsed immediately in three changes of sterile distilled water and air dried for few minutes. After sterilization, broccoli heads (2 kg each) were packed in oriented polypropylene bags (1040x1080mm, thickness 30 µm) with two holes (5mm diam) on both sides. A packed of 200g silica gel with 100 ml food grade ethanol was added in each pack. Ethanol vapor gradually diffused from the silica gel and exposed broccoli during storage. The ethanol treated and untreated broccoli samples were stored for 10 days in two different storage temperatures; 17±0.20C with an RH of 74±4.7 % and 22±0.20C with an RH of 66.8±1.5 %. Untreated broccoli samples were similarly packed and stored but without a pack of ethanol vapor. Chlorophyll degradation, weight loss, total soluble solid, nutrient content and organoleptic quality of ethanol treated and untreated were evaluated at five destructive sampling period (n=3) on 0,3,5,7 and 10 days in storage.

Biochemical Analysis of Treated and Untreated Broccoli Samples after Storage

Chlorophyll Measurement of Stored Treated Samples. Chlorophyll A and B are photosynthetic pigments found in chloroplast that imparts green color in the cell. During the natural respiration of fruits and vegetables, biochemical changes take place and the chloroplast containing the chlorophyll will be converted to chromoplast. Measurement of chlorophyll content within the chloroplast is a good index of ripening in fruits and vegetables.

Chlorophyll content was analyzed using (AOAC Official Methods of Analysis 942.04 chlorophyll in plants: Spectrophotometric Method for Total Chlorophyll and the individual and b components). Two grams were cut using sterilized sharp cutter blade, one hundred (100) mg of CaCO3 was then added to neutralize plant acid and prevent pheophytin a formation. The samples together with 30 ml acetone were homogenized in a blender for three minutes in high speed. The homogenate was centrifuged at 3000 rpm for five minutes. Chlorophyll was determined from the aliquot of the clear extract with the use of spectrophotometric analysis. Absorbance readings against 100% acetone in a UV-Vis spectrophotometer at four wavelengths were taken.

750 nm (A750 = 0 for clear extract)
662 nm (chlorophyll a maximum using 100% acetone)
645 nm (chlorophyll b maximum using 100% acetone)
520 nm (for extracts from green plant tissue, A520 should be < 10% of A662)

Determination of Nutritional Quality of Broccoli after Storage. Fruits and vegetables such as broccoli provide optimum mix of antioxidants, such as Vitamin C, polyphenols and carotenoids. Phenolic compounds represent a major portion of the antioxidants found in many plants (Ness et al., 1997 & Eastwood, 1999).

Total phenolic in broccoli samples were determined using spectrophotometric analysis using Folin-Ciocalteu reagent (Luximon et al. 2002). Absorbance reading at 685 nm was taken using Gallic Acid as reference.

Extraction of ß-carotene was carried out by weighing five grams of broccoli samples and placed in a waring blender and 40 mL of acetone, 60 mL hexane, 0.1 gram $MgCO_3$ were added and blended for five minutes. The residues were washed with 25 mL acetone and 25 mL hexanes twice then with 50 mL distilled water thrice then transfer the hexane layer to 100-mL volumetric flask and dilute to mark with acetone-hexane (1+9). Beta carotene was determined using Spectrophotometric analysis. Absorbance of the solution was read at 440 nm.

Ascorbic acid content of broccoli samples was determined by titration against indophenol reagent. 50 g of the samples were mixed with water and blend for one minute. The mixture was filtered to obtain the juice. Preparation and standardization of Indophenol solution was carried out by weighing 25 mg of ascorbic acid then dissolved in 100 ml of 0.4% Oxalic acid. 1 ml of the aliquot was titrated using a micro burette with 0.04% indophenol solution to a rose pink endpoint.

Dye factor = mg ascorbic acid/ volume of indophenol solution

Calculation:
Mg ascorbic acid = (f x t x volume of extract x 100)

Volume of sample x weight of sample:
Where: f=dye factor
t= amount of dye required for titration

Determination of Total Soluble Solids Content. Sugar is the main component of total soluble solids (TSS) in most fruits and vegetables. Measurement of TSS therefore provides a sensible gauge of onset and peak of ripening in certain commodities.Total soluble solid (TSS) was determined before and after treatment of ethanol vapor. TSS was measured by placing a drop of the clear puree sample in the refractometer. The amount of total soluble solids was read on the line formed by the light and dark area.

Determination of Percentage of Weight Loss (%WL). Initial weight of samples was recorded before ethanol vapor exposure, and every sampling period until the end of storage period. Weight loss was computed based on the formula below.

$$\frac{\textit{Initial weight- Final weight}}{\textit{Initial weight}} \; x\ 100$$

Determination of Organoleptic Quality of Broccoli after Storage. Organoleptic quality of samples was determined at day 0, 3, 5, 7 and 10 days after storage through evaluation of five parameters. Each parameter was scored on a scale with reference to dehydration, visual microbial development, exuded present, unpleasant odor and browning. (Table 1) Each treated broccoli head within the package were evaluated individually for every parameter. A lesser score indicates a better organoleptic quality.

Sensory Evaluation

Sensory analysis on ethanol vapor treated and untreated samples were carried out with 10 judges who assessed the presence of off- odors and off-flavors, and evaluated aroma, texture, flavor, florets color, and the overall acceptability. The following hedonic scales were used by judges to compare treatments.

Table1. Physical parameters and their corresponding scale for evaluating organoleptic quality

No.	Physical parameters	Scale and scores
1	Dehydration	0(without),1 (slight), 2 (10-40 % surface affected), 3 (>40% surface affected)
2	Visual mold and bacterial development	0(absent), 1(slightly visible), 2 (10-40% surface infected), 3(>40% surface infected)
3	Unpleasant odour	0(absent), 1(slightly present),2 (severe)
4	Exuded present	0(without), 1(with)
5	Browning	0(without), 1(slightly visible), 2 (10-40% surface with browning)

Table 2. Physical parameters and their corresponding scale for evaluating sensory quality

No.	Physical parameters	Scale and scores
1	Aroma and taste	0=flat, 1=very weak, 2=weak, 3=moderate, 4=strong, and 5=very strong;
2	Texture	1=very soft, 2=soft, 3=intermediate, 4=firm, and 5=very firm;
3	Florets colour	1=green, 2= slightly green, 3=slightly yellow, and 4=yellow
4	overall acceptability	1=dislike, 2=dislike moderately, 3=neither like nor dislike, 4=like moderately, and 5=like extremely.

Experimental design

Experiments were analysed using factorial complete randomized design in three replicates. Data were analysed for statistical significance using Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Biochemical Analysis of Ethanol Vapour Treated and Untreated Broccoli Samples after Storage

Effect of Ethanol Vapor on Chlorophyll Degradation of Broccoli during Storage. The total chlorophyll content of broccoli heads decreased in all treatments during storage. Rate of chlorophyll degradation however was slower in broccoli treated with ethanol vapour and stored at the lower storage temperature of 17±0.30C. At 3 days, untreated broccoli stored at 22±0.20C has reached 73.2% chlorophyll degradation with slight green and almost uniformly yellow color, while those stored at lower temperature of 17±0.30C has slight yellow and almost uniformly green colour and chlorophyll degradation of 30.3%.

In 2013, studies by Page et al. reported that storage of broccoli at 4^{0}C showed no sign of yellowing until 11 days, thus low temperature delays both visible senescence and chlorophyll degradation in broccoli.

The chlorophyll degradation in ethanol-treated broccoli was even slower in those stored at the lower temperature of 17±0.3^{0}C. At three days, percent degradation was 2.4 which progressed up to 60.5 % on the 10th day. At 60.5% chlorophyll degradation, 80% of the broccoli retained its green color. The same visual condition was reached in ethanol-treated broccoli stored at 22±0.2^{0}C at seven days. Ethanol vapor delayed the senescence of broccoli up to 10 days when stored at 17±0.3^{0}C and 7 days at 22±0.2^{0}C.

Determination of Nutrient content of Broccoli after Storage. ß-carotene decreased with time in both treated and untreated broccoli samples. Decrease, however, was faster in the broccoli heads stored at higher temperatures (22±0.2^{0}C) than in the lower temperature (17±0.3^{0}C) (Table 4). With ethanol added, degradation of ß-carotene nutrients is further slowed down, 24.55% at higher temperature and 1.60% at lower temperature in five days storage period.

For the total phenolics and ascorbic acid content, the addition of ethanol vapour seemed to have prevented the deterioration of the broccoli at five days at lower temperature. There was however no advantage in adding ethanol in broccoli head stored for five days at higher temperature. Based on results, the ß-carotene nutrient is positively affected by ethanol vapor, such that it controlled the deterioration of the broccoli.

Table 3. Percent degradation of total chlorophyll of broccoli treated with 5 % ethanol vapor

Days in storage	**17±0.30C**		**22±0.20C**	
	Untreated	5% ETOH	Untreated	5% ETOH
3 DAT	30.3^{e}	2.4^{f}	73.2^{b}	22.2^{e}
5 DAT	62.5^{bc}	29.2^{e}	87.5^{a}	48.2^{d}
7 DAT	85.4^{a}	45.2^{d}	92.3^{a}	64^{bc}
10 DAT	92.4^{a}	60.5^{c}	*	*

*Legend: * rotten*

Table 4. Nutrient analysis of broccoli during storage

Storage Time	**Nutrient Content**					
	Beta -carotene (μg/100g)		Total Phenolic assay [Gallic Acid Equivalent](mg/100g)		Ascorbic Acid (mg/100g)	
	$17±0.3^{0}$C	$22±0.2^{0}$C	$17±0.3^{0}$C	$22±0.2^{0}$C	$17±0.3^{0}$C	$22±0.2^{0}$C
Initial	1047.37±4.14 f(o)	1047.37±4.14 f(o)	107.10±0.4 f(o)	107.10±0.42 f(o)	37.40±0.14 f(o)	37.40±0.14 f(o)
Day 5						
Treated	1030.37±4.72 f(1.6)	790.95±10.85 b(24.4)	116.14±1.00 g (^{0})	73.74±0.08 d 31.1	19.1±0 e 48.9	15.40±0.26 d 58.8
Untreated	857.02±3.97 c(18.1)	627.92±27.7 la(40)	45.14±0.50 b(57.8)	66.43±1.64 c(37.9)	15.69±0.32 d(58.0)	11.37±0.18 c(69.5)
Day 10						
Treated	944.39±20.58 d(9.8)		9.24±1.67 e (7.33)		9.06±0.16 b (75.7)	
Untreated	993.81±2.97e (5.1)		29.53±0.21 a (72.4)		5.52±0.26 a (85.2)	

For the total phenolics and ascorbic acid content, the addition of ethanol vapour seemed to have prevented the deterioration of the broccoli at five days at lower temperature. There was however no advantage in adding ethanol in broccoli head stored for five days at higher temperature. Based on results, the ß-carotene nutrient is positively affected by ethanol vapor, such that it controlled the deterioration of the broccoli.

During the process of ripening, chloroplasts in chlorophyll changes to chromoplast, and this is a natural change as senescence progressed. The chloroplast contained 30 to 40% of the health promoting compounds such as ascorbic acid and other phytochemicals (Gerhardt, 1964; Foyer et al., 1983). In this study, high retention of nutrient content in the ethanol treated broccoli under the two storage condition was related to the inhibition effect of ethanol vapor on the rapid chlorophyll degradation. Ethanol vapor inhibited the rapid degradation of chlorophyll in the ethanol treated broccoli heads thereby high portion of chloroplast was retained in chlorophyll and consequently retained high levels of important nutrients in broccoli. In untreated broccoli, the rapid degradation of chlorophyll resulted in higher numbers of chromoplasts which subsequently caused loss of more nutrient content.

Effect of Ethanol Vapor in Total Soluble Solids. TSS contents decreased in all broccoli samples regardless of treatment and storage condition (Table 5). Significant reduction was observed in untreated broccoli stored at both 17±0.30C and 22±0.20C right after three days in storage. A TSS content of treated broccoli was maintained until seven days in storage and reduction was only observed after 10 days of storage. During the process of respiration in fruits and vegetables, there is an initial increase in TSS content and followed by decrease during the later stage of storage. This could be due to the breakdown of polysaccharides into water soluble sugar, and as storage time advances TSS content declines. The higher the respiration rates, the faster the breakdown of chemical components of certain fruits and vegetables such as TSS. In this study rapid reduction of TSS contents in ethanol treated broccoli was inhibited because respiration rate was slowed down by the inhibition of rapid ethylene production through ethanol vapor treatment. Consequently, rapid breakdown of important macromolecules such as polysaccharides and starch were regulated.

Effect of Ethanol Vapor on Weight Loss of Broccoli during Storage. Weight loss of untreated broccoli stored at both temperatures increased rapidly, with a final value of 2.79% over 10 day storage at 17 ± 0.3^{0}C. Untreated broccolis stored at higher temperature of 22 ± 0.2^{0}C increased more weight loss level of 4.95% which already exceeded the 4% acceptable limit. In contrast, the weight loss for those ethanol treated broccoli was lower with a final value of 2.39 for over 10 day in storage at 17 ± 0.3^{0}C and 3.30 % for over seven days at 22 ± 0.2^{0}C (Table 5). Weight loss below 4% of their initial weight is acceptable to avoid wilting and senescence symptoms of broccoli (Vallejo et al. 2003). This means that ethanol vapor extended the shelf-life of broccoli by reducing weight loss during storage. The greater weight loss from untreated samples could be due to the more advanced stages of senescence in untreated broccoli than in treated samples.

Table 5. Total soluble solid and % weight loss of broccoli after storage

	Treated with 5 % ethanol vapour			
Exposure time	Total soluble solids		% weight loss	
	17 ± 0.3^{0}C	22 ± 0.2^{0}C	17 ± 0.3^{0}C	22 ± 0.2^{0}C
Initial	4.26^{e}	4.26^{e}	0^{a}	0^{a}
Day 3				
Control	4.2^{e}	3.07^{bc}	0.47^{abc}	1.91^{abcdef}
Treated	4.27^{e}	3.9^{d}	0.35^{ab}	0.52^{abc}
Day 5				
Control	3.9^{d}	2.5^{a}	0.82^{abcd}	3.06^{ef}
Treated	4.23e	4.4^{e}	0.37^{ab}	1.15^{abcde}
Day 7				
Control	4.03^{e}	2.83^{ab}	2.77^{def}	4.95g
Treated	4.1^{e}	3.47^{cd}	2.04^{bcdef}	3.30fg
Day 10				
Control	2.6^{ab}	*	2.79^{def}	*
Treated	3.47^{cd}	*	2.39^{cdef}	*

* Samples were totally rotten

Effect of Ethanol Vapor on Organoleptic Quality (OQ) of Broccoli during Storage. Five parameters were used to determine the organoleptic quality of ethanol treated and untreated broccoli during storage (Table 6). Quality in all broccoli samples decreased with storage time. Broccoli treated with 5% ethanol vapour maintained its good quality until five days after treatment in storage. Manifestation of rapid florets' dehydration, browning, production of unpleasant odor and exudate were slowed down. Microbial development was also inhibited up to five days.

In contrast, those untreated broccoli stored at 17±0.3^{0}C and 22±0.2^{0}C exhibited slight to 40% florets' dehydration and browning, respectively. Slight microbial infection was also visible immediately after three days in storage. Quality loss even progressed to more than 40% dehydration, browning and > 40% microbial infection. Moreover, all broccoli held at 22±0.20C were already rotten after seven days of storage. The delayed manifestation and development of decay in treated broccoli was related to the effect of ethanol vapour as it has been known and widely used as anti-microbial agents in several commodities (Thambaramaya, 1997). Ethanol did not completely control the growth of fungi and bacteria in treated broccoli, however it inhibited the rapid growth and development thus prolonging the good visual quality of broccoli.

Table 6. Organoleptic quality of broccoli during storage

	17±0.3^{0}C		22±0.2^{0}C	
Exposure Time	**5% ethanol vapor**	**untreated**	**5% ethanol vapor**	**untreated**
Initial	0	0	0	0
3 DAT				
Dehydration	0	0	83.0	58 2.5
Microbial infection	0	0.16	0	1
Unpleasant odour	0	0	0	1
Exuded present	0	0	0	0
Browning	0	1.66	0.83	3
5 DAT				
Dehydration	1	3	2.33	3
Microbial infection	0	0	1.33	3
Unpleasant odour	0.33	1	1	1
Exuded present	0	0	0	0
Browning	1	3	2	3
7 DAT				
Dehydration	1.5	3	2	3
Microbial infection	1	1.5	2.08	3
Unpleasant odour	0.5	1.5	1.25	2
Exuded present	0	0.5	0.25	1
Browning	1.5	3	2.1	3
10 DAT				
Dehydration	2	3	*	*
Microbial infection	3	3		
Unpleasant odour	2	2		
Exuded present	1	1		
Browning	2	3		

* Samples were totally rotten

Effect of Ethanol Vapor on the Sensory Qualities of Broccoli during Storage. Sensory analysis of broccoli during storage was conducted to determine the acceptability of ethanol treated broccoli (Table 7). In terms of aroma and taste 50, 60, 40 and 50% of panellists gave "flat" score to treated and untreated broccoli stored at 17±0.30C and 22±0.2 0C respectively. Flat taste and aroma given by panellists' means that they did not detect any difference in taste and aroma between the ethanol treated and untreated broccoli. Treatment of ethanol vapor does not cause any tainted taste to broccoli.

In terms of texture, majority of panellist (60%) assessed the treated and untreated broccoli in 17±0.30C as "soft" in texture. For overall acceptability, 50% of panellists assessed all broccoli samples regardless of treatment as neither like or dislike. The finding that ethanol vapor has no detrimental effect on the sensory attribute makes it a potential treatment in prolonging shelf life of broccoli.

CONCLUSION

Senescence of ethanol-treated broccoli stored at 17±0.3^{0}C has a slower rate of chlorophyll degradation. Thus, yellowing of broccoli heads was inhibited up to 10 days and seven days in those that were stored at 22±0.2 ^{0}C. Organoleptic properties were maintained up to seven days in ethanol treated broccoli stored at 17±0.3^{0}C and five days in those that stored at 22±0.2 ^{0}C. Ethanol vapor (5%) will prolong the shelf life and maintain the overall quality of broccoli (green florets and without microbial infection) by five and seven days at 22±0.2^{0}C and 17±0.3^{0}C storage temperature, respectively. Ethanol vapor has no effect on the sensory quality of broccoli.

Table 7. Response (%) of judges for sensory evaluation of broccoli during storage

Sensory Parameter	Storage temperature			
	17±0.3^{0}C		22±0.2^{0}C	
Aroma and taste				
Flat	50	60	40	50
Very weak	0	0	10	20
Weak	30	30	10	10
Moderate	10	10	30	10
Strong	10	0	10	10
Very strong	0	0	0	0
Texture				
Very soft	0	10	0	10
Soft	60	60	10	30
Intermediate	30	30	40	50
Firm	10	0	50	0
Very firm	0	0	0	10
Colour				
Yellow	0	50	0	80
Slightly yellow	50	50	10	20
Slightly green	40	0	60	0
Green	10	0	30	0
Overall acceptability				
Dislike	10	10	10	20
Moderately dislike	40	10	20	30
Neither like nor dislike	50	60	20	50
Like moderately	0	20	50	0
Like extremely	0	0	10	0

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DEVELOPMENT AND OPTIMIZATION OF CACAO POD HUSK AS FUEL BRIQUETTES

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ABSTRACT

Cacao beans are primarily used in chocolate processing. However, the entire processing operation generates a substantial quantity of pod husk of about 77% of the whole weight of cacao pods. In traditional practice, the cacao processors prefer to collect only the cacao beans leaving the cacao pods in the field unutilized. This generates foul odor and becomes inoculum of black pod rot and pathogens etc. Cacao pod husk has a high heating value, a large amount of dry matter and low ash content that can be utilized as a source of alternative energy. Converting cacao pod husk into fuel briquettes will add value to the product and at the same time address the problem of waste disposal. The general objective of the study was to develop an environment-friendly fuel briquette sufficient to resist impact during handling and transport and produce the required heat for domestic cooking and also for industrial application.

Six (6) formulations in producing cacao pod husk-based fuel briquettes were developed using piston type briquetting machine. Results showed that the 10% binding agent and cacao pod husk with particle size ≤ 2.2 mm obtained the highest bulk density (0.75 g/cc), shatter resistance (99.93%) and break strength of fuel briquettes (0.114 kN). It was observed that the higher amount of binding agent and smaller particle size of cacao pod husk has resulted in higher quality fuel briquettes. The optimum formulated fuel briquette has an average compressive strength, average energy density and thermal efficiency of 4.18 MPa, 2,412.55 cal/cc and 26%, respectively. Likewise, the energy demand in producing a ton of briquettes was only 10.93% of the energy contained in a ton of cacao pod husk briquettes with a value of 3,741.1 kWh.

Keywords: Cacao Pod Husk, Fuel Briquettes, Physic-chemical Properties, Thermal Properties

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INTRODUCTION

Cacao (Theorem cacao L.) is a very important beverage crop, next to coffee and tea. It is one of the most important crops and a major agricultural commodity traded worldwide. It is considered as a cash crop for growing countries and a key import for processing and consuming countries. It is also consumed as chocolate confectionery, chocolate coated products such as biscuits, ice cream, or in other food products containing cocoa powder like cakes, snacks and baked products.

World Cocoa Foundation (2012) reported that the world production of cacao continues to increase in absolute terms from 3.66 million metric tons in 2007-2008 to 3.98 million metric tons in 2011-2012. On the other hand, the Food and Agriculture Organization reported that the world production of cacao in 2016 was 4.47 million metric tons planted in 10.2 million hectares. Africa is the principal cocoa producer with 63.3 % market share or a total of 2.5 million metric tons concentrated mainly in Ghana and Ivory Coast. Asia and Oceania, on the other hand, contributed about 18.8 % of the total world production or about 718,000 tons, the bulk (602,000 tons) came from Indonesia (FAO, 2017).

With the increasing world consumption of chocolates, the global demand had been exceeding the global supply. Netherlands is the top importer valuing to 2.076 billion USD in 2009. Also, demand is growing more rapidly in Asia where there is a strong economic growth, particularly in India and China resulting in more people being able to afford luxury foodstuffs such as chocolate (Sun Star Davao, 2012).

The cocoa production in the Philippines shows a potential for expansion since the country is ideal for cacao growing particularly in Mindanao. For instance, about two million hectares planted with coconut is “highly suited” to be inter-planted with cacao. As of 2012, the Philippines produced around 4,831 metric tons of cacao, the bulk coming from the Davao Region with 3,763 metric tons of production (BAS, 2013). The initiative to intensify and revive the local cacao industry has been started through the efforts of the government, international organizations, private entrepreneurs and the Cocoa Foundation of the Philippines (Cocoa Phil) in particular by developing a Philippine Cacao Roadmap. The roadmap envisioned to produce 100,000 tons of fermented cacao beans.

Cocoa beans are primarily used in chocolate processing. However, the entire processing operation generates a substantial quantity of pod husk approximately between 70 to 75% of the whole weight of cacao or 700 to 750 kg of pod husk are generated for every ton of cacao fruit (Cruz et. al. 2012). With the current cacao production in the country, around 3,382 metric tons pods are wasted every year. Traditionally, the cacao processors prefer to collect only the cacao beans, leaving the cacao pods in the field unutilized. These generate foul odor and become inoculum of black pod rot and other pathogens. (CocoaPhil, 2012).

Some authors explored the utilization of cacao pods/ husks as gel forming and animal feed materials, and for pharmaceutical applications. Likewise, Eghosa et al. (2010) reported that cacao pod husk has high heating value, a large amount of dry matter and low ash content. Utilization of these materials as a source of alternative energy, particularly converting it into densified material or briquettes will add value to the product and at the same time address the problem of waste disposal. The project sought to develop and optimize environment-friendly fuel briquettes product sufficient to resist the impact during handling and transport and produce the required heat for domestic cooking and for industrial application.

METHODOLOGY

Collection of Experimental Samples

Five commonly cacao clones such as UF18, BR 25, PBC 123, K1 and K2 were selected and used in the experiments. The samples were collected from nearby barangays in Talandang, Davao City. Each cacao pod was weighed and recorded before pod splitting.

The weight of the pod husk and wet beans were also recorded. Likewise, the initial moisture content of the pod husks was also undertaken following the procedure described by Nyadanu et. al. (2011).

Determination of Chemical Properties of Cacao Pod Husk

A representative sample of the cacao pod husk was collected for proximate chemical analysis. The proximate chemical analysis was undertaken following the ASTM D-3172 standard procedure.

Optimization in the Production of Cacao Pod Husk Fuel Briquettes

Figure 1 shows the process flow for the production of cacao pod husk-based fuel briquettes. The production of briquettes was conducted using a piston-type briquetting machine. The biomass was punched into a die by a reciprocating ram with a very high pressure that compressor the mass to obtain a compacted product.

For water binder and cassava starch were vigorously mixed and cooked until a desired consistency was achieved. The prepared binder was added to the hammer milled cacao pod husk and mixed using a mechanical mixer. Mixing of the materials was carried out for 5 min until the mixture became homogeneous and attained the uniform particle distribution and consistency. The produced mixture was unloaded from the mixer to a container and kept until it was ready for densification. The percent binding agent or the weight of cassava starch was computed based on the dried biomass by weight prior to mixing and briquetting operation. A 100 grams of the mixture was weighed and loaded on the molder of the briquetting machine. Based on the preliminary trial results, three different percentage of the binding agent (0, 5 and 10) and three particle sizes (>3.2 mm, 3.2–2.2 mm) were considered in the study.

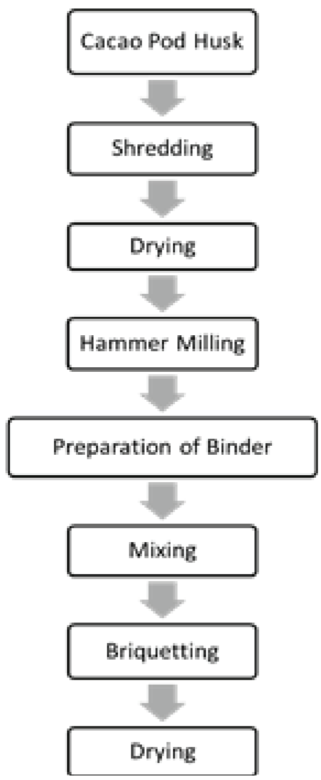

Figure 1. Process flow for the production of cacao pods husk based fuel briquettes

The particle size was determined using standard sieves (3.2 and 2.2 mm mesh). Likewise, the number of briquettes produced, time of loading and unloading and briquetting were recorded.

Determination of Physical and Mechanical Properties of Briquettes

The physical and mechanical properties such as density shatter resistance and compression strength were evaluated and analyzed.

Bulk Density. The density of the produced fuel briquettes was determined after sun drying by measuring the volume and weight of five samples. Weighing of samples was performed using the analytical balance (Pioneer, OHAUS Corporation) and the dimensions were measured using a vernier caliper. The density was calculated by determining the ratio of mass and volume of the fuel briquettes.

Shatter Resistance. The shatter resistance of the dried cacao pod husk fuel briquettes was measured to determine its durability during handling and transport. The shatter resistance test may simulate the forces encountered during emptying of densified products from trucks into the ground, or from chutes into bins (Kaliyan et al. 2009).

The shatter resistance of briquettes was determined by following the procedure described by Ghorpade (2006). Representative briquettes from six formulations were selected for the drop test. The briquette with known weight and dimensions was dropped on the concrete floor from the height of one meter. The weight of disintegrated briquettes and its size was recorded. The performance of the briquettes was expressed as the resistance to produce fine particles. This means good performance would be indicated by a greater mass fraction of 6.35 millimeter particles remaining after the drop tests. The shatter resistance of the briquettes was calculated using the following formula:

$$\%\ \text{Weight loss} = \frac{W1-W2}{W1} \times 100$$

% Shatter Resistance= 100 - % weight loss

Where,

W1 = weight of briquette before shattering
W2 = weight of briquette after shattering

Compressive Strength. Compressive resistance test simulates the compressive stress due to the weight of the top briquettes on the lower briquettes during storage in containers. The hardness of the produced briquettes was determined using universal testing machine (Instron Model). Compressive resistance of the densified products was determined by diametrical compression test. The flat surface of the briquette sample was placed on the horizontal metal plate of the machine. A five kilo newton-load was used at a cross head speed of 10 mm/min until the briquette failed by cracking or breaking.

Energy Density. Clarke (2011) defined energy density as the term used to describe the amount of energy stored per unit volume. Compaction or densification is one way to increase the energy density. The energy density of the fuel briquettes was determined by multiplying its bulk density by the heating value of the biomass.

Determination of Thermal Properties of Briquettes

Calorific Value. The calorific value is an indication of the energy the material possessed as a potential fuel. The calorific value of the produced briquettes was determined using LECO AC-350. The test was done at the Forest Products Research and Development Institute (FPRDI) of the Department of Science and Technology.

Thermal Efficiency. The thermal efficiency is otherwise known as percentage heat utilized or energy. This was measured using the water boiling test as described by Rathore (2008). The volume of the kettle was measured and filled with 2/3 of water. The kettle with a cover was placed on top of the charcoal stove.

A thermometer was fixed in the central part of kettle. A 500g of briquettes was measured for testing. The ambient temperature and initial temperature of water in the kettle were measured. The final temperature of the water after boiling was observed. The water was heated until the briquettes were used up, then the kettle cover was moved away and evaporation was continued for 20 minutes. Afterwards, the kettle was separated from the stove; the temperature of the kettle was lowered for two hours and the volume of water was measured. The thermal efficiency was calculated using the formula stated below. The numerator gives the net heat supplied to the water while the denominator gives the net heat liberated by the fuel.

$$\text{Thermal efficiency} = \frac{(W_i\, C_p\, (T_2\text{-}T_1)+(L(W_i\ \text{-}W_f)}{\textit{Quantity of fuel used x calorific value}}$$

Where:

Wi : initial volume of water, kg
Wf : final volume of water, J/kg °C
T1 : initial temperature of water, °C
T2 : final temperature of water, °C
Cp : specific heat of water, J/kg °C
L : latent heat of water = 540 kcal/kg

Energy Balance. The data were collected from the CocoaPhil, Biao, Talandang, Davao City with a production time of eight hours, Two employees and one piston-type briquetting machine were used to produce cacao pod husk fuel-based briquettes. Other equipment used were shredder, hammer mill and mixer. Liquified petroleum gas (LPG) was used to gelatinize the mixture of cassava starch and water.

Six steps were considered in the computation of the energy balance of cacao pod husk fuel-based briquettes: 1) shredding, 2) hammer milling, 3) binder preparation, 4) mixing, 5) briquetting, 6) drying.

The relationship between the energy used for production and energy contained in cacao pod husk briquettes was computed using equation 1 (Gentil and Vale, 2014).

Where:

ξ1 - energy needed to produce one ton of briquettes (kWh);

ξ2 - calorific energy contained in one ton of briquettes (kWh).

The energy needed to produce one ton of cacao pod husk briquettes was determined by considering the electric and human energy involved in the production of briquettes.

Electric energy. Shredder, hammer mill, mixer and briquetting machine consumed electric energy with the following power: 0.746 kW, 3.728 kW, 0.746 kW and 1.491 kW, respectively.

Human energy. The human energy computation according to Gentil and Vale (2014) based on the study of Silva (2001). Equation 2 was used to determine the total human energy used in the production of one ton of cacao pod husk briquettes.

$$\text{Eht} = ED * DT * NF * 10\ \text{-}6$$

Where:

Eht - total human energy (MJ/month);
ED-15.884 J/day (SILVA, 2001);
DT-working days per month;
NF-number of employees in the industrial process

Statistical Analysis. The data gathered were analyzed using 3x3 factorial in completely randomized design (CRD). ANOVA table was utilized to determine the level of significance among treatments. The difference among means was analyzed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Description of Cacao Pods

Table 1 presents the description of cacao clones used in the study. The average weight of cacao pods was 588.27 grams. The K2 clone had the highest percentage of cacao pod husk with a value of 80.24% ± 1.82 followed by PBC123

(77.41% ± 1.19), BR25 (75.63% ± 3.11), K1 (73.99% ± 2.25) and UF18 (73.69% ± 3.99). The initial moisture content of pod husk ranged from 89.21%±1.27 to 90.10%±0.93.

With the projected production of 100,000 metric tons of fermented dried beans in the year 2020 and beyond, the cacao industry can generate approximately 633 million kg of cacao pod husks.

Chemical Properties of Cacao Pod Husk

Figure 2 shows the chemical composition of cacao pod husk. The combustible volatile matter and fixed carbon content of pod husk obtained ranges from 60.89% to 64.69% and 27.16% to 29.69%, respectively. High volatile matter content will produce low ignition and temperature; faster ignition, devolatilization and burning; produces more combustible gas and inorganic vapor; volatile matter oxidizes faster than the char; better and faster burnout with lower unburned carbon in ash due to improved combustion; and biochar formation with the high specific surface area.

On the other hand, during biomass conversion, fuel with a low amount of fixed carbon reduces the carbon dioxide emission. However, the main environmental benefit of biomass fuel is, carbon dioxide emission from biofuels is considered CO2-neutral for greenhouse gas effect (Vassilev et al., 2015).

Table 1. Description of cacao pods

Clones	Ave. Weight, g			Initial MC of Husk, %
	Pods	**Husk**	**Percent Pod Husk**	
UF18	717.20	529.40	73.69 ± 3.99	93.37 ± 3.30
BR25	499.40	379.00	75.63 ± 3.11	88.88 ± 2.49
K2	641.70	515.30	80.24 ± 1.82	89.31 ± 1.86
PBC123	558.30	431.80	77.41 ± 1.19	90.10 ± 0.93
K1	525.00	388.73	73.99 ± 2.25	89.21 ± 1.27
Average	**588.27**	**448.44**	**76.29**	**90.17**

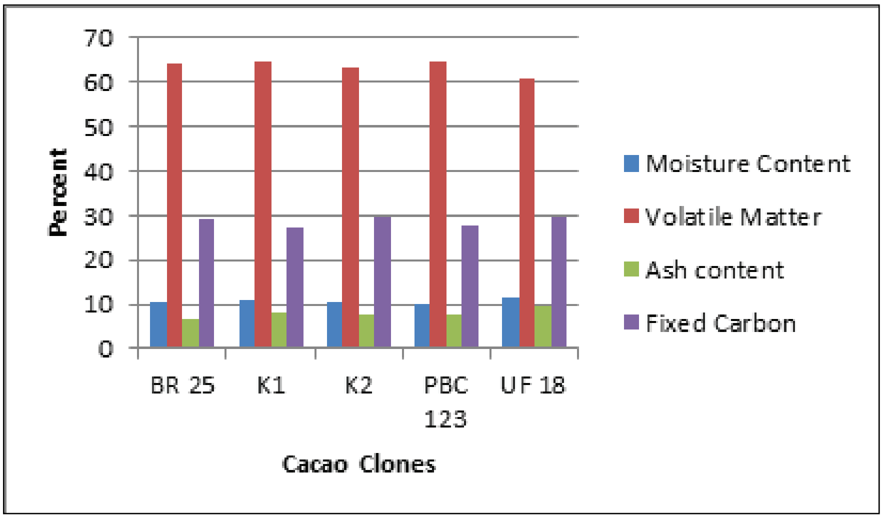

Figure 2. Chemical composition of cacao pod husk

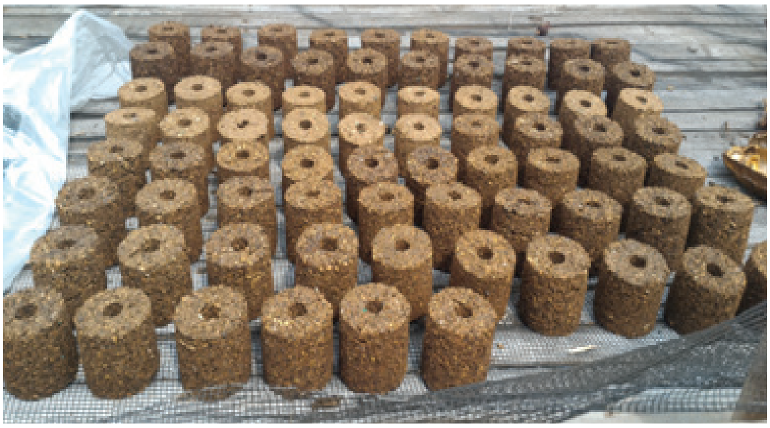

Figure 3. Cacao pod husk based fuel briquette

Table 2. Bulk density of cacao pod husk based fuel briquettes, g/cc

Particle Size	Binding Agent			
	0%	5%	10%	Average
>3.2 mm	0.46±0.03	0.47±0.02	0.48±0.02	**0.47**[c]
>2.2 ≤3.2mm	0.46±0.01	0.51±0.02	0.54±0.01	**0.50**[b]
≤2.2 mm	0.56±0.02	0.56±0.03	0.75±0.02	**0.62**[a]
Average	**0.49**[b]	**0.51**[b]	**0.59**[a]	

Average or means with the same superscript letters within column indicate no significant difference (p <0.05)

Physical Properties of Briquettes

Figure 3 shows the cacao pod husk based fuel briquettes. The briquette was cylindrical with a hole in the center to promote efficient combustion. The size of briquette was 50 mm in length with an outside and inside diameter of 50 mm and 16 mm, respectively. The briquettes were sundried from an initial moisture content of 43-51% (wb) down to 6-8 % (wb). It is not advisable to dry the briquette below 6% because of possible moisture intake and expansion of the material. Li and Lui (2000) reported that briquette with moisture content of ≤4% become fragile due to expansion caused by moisture absorption.

Bulk Density. Table 2 shows the computed bulk density of cacao pod husk-based fuel briquettes. The highest and lowest bulk density of cacao pod husk fuel briquettes obtained were 0.97±0.01 kg/ cc and 0.67±0.020.46 kg/ cc, respectively. The bulk density was directly proportional to the percent binding agent and inversely proportional to the particle size of cacao pod husk.

The fine particles made compaction process easier, provided fewer pore spaces and more mass of the material per given volume. Tumuluru et al. (2010) Oladeji et al. (2009) and Tuates et al. (2015) reported that the less pore spaces, more weight of the material per volume and denser briquettes. The briquettes with high bulk density make handling easier, reduce transport, handling and storage cost, and improves combustion its properties (Grover and Mishra, 1996). The analysis of variance revealed significant differences (p < 0.05) on the particle size of the biomass and the amount of binding agent applied.

S***hatter Resistance.*** Shatter resistance is the force applied to the briquettes during unloading from trucks onto the ground (Kaliyan and Morey, 2009). The shatter resistance of cacao pod husk based fuel briquettes ranged from 93.32%±3.18 to 99.93%±0.12 (Table 3). The shatter resistance is directly proportional to the percent binding agent and inversely proportional to the particle size of cacao pod husk. Kaliyan and Morey (2009) and Tuates et al. (2015) reported that particle size of biomass has positively affected the quality of the briquettes. However, cacao pod husk based fuel briquettes required a minimal amount of binder because it contains lignin that also serves as a binder (Daud et al. 2013). The cacao pod husk based briquettes were higher than the recommended shatter resistance level of 50% for coal briquettes (Richards, 1990).

The analysis of variance revealed significant differences ($p < 0.05$) on the particle size of the biomass but there was no significant difference in the amount of binding agent applied.

Compression Test. Breaking strength or hardness is the maximum load that a briquette can withstand before breaking (Kaliyan and Morey, 2009). The briquettes will expose compressive stress during handling, transport and storage (Richards, 1990). The breaking strength of cacao pod husk based briquettes under cleft failure condition varied 0.003±0.002 MPa to 0.114±0.013 MPa (Table 4). The percent binding agent is directly proportional to the breaking strength. While particle size is inversely proportional to the compressive strength. Briquettes with large particle size have low breaking strength because it has more fissure points that produce cracks and fractures (Kaliyan and Morey, 2009).

Table 3. Impact resistance of cacao pod husk based fuel briquettes, %

Particle Size	Binding Agent			
	0%	5%	10%	Average
>3.2 mm	89.99±7.62	97.06±1.05	98.89±0.21	**93.32^{b}**
>2.2 ≤3.2mm	99.57±0.57	99.32±0.31	99.81±0.19	**99.57^{a}**
≤2.2 mm	99.85±0.25	99.93±0.12	99.93±0.12	**99.85^{a}**
Average	**97.58**	**98.77**	**99.54**	

Average or means with the same superscript letters within column indicate no significant difference (p <0.05)

Table 4. Compressive breaking point of cacao pod husk based fuel briquettes, kN

Particle Size	Binding Agent			
	0%	5%	10%	Average
>3.2 mm	0.003±0.00	0.005±0.00	0.008±0.00	**0.005^{c}**
>2.2 ≤3.2mm	0.010±0.00	0.010±0.00	0.020±0.00	**0.014^{b}**
≤2.2 mm	0.023±0.00	0.027±0.00	0.114±0.1s0	**0.055^{a}**
Average	**0.012±0.00^{b}**	**0.014^{b}**	**0.047^{a}**	

Average or means with the same superscript letters within column indicate no significant difference (p <0.05)

Table 5. Energy density of cacao pod husk based fuel briquettes, cal/cc

Particle Size	Binding Agent			
	0%	5%	10%	Average
>3.2 mm	1,479.70±0.03	1,511.86±0.02	1,544.03±0.02	**1,511.86^{c}**
>2.2 ≤3.2mm	1,479.70±0.01	1,640.53±0.02	1,737.03±0.01	**1,619.09^{b}**
≤2.2 mm	1,801.37±0.02	1,801.37±0.03	2,412.55±0.02	**2,005.10^{a}**
Average	**1,586.92^{b}**	**1,651.25^{b}**	**1,897.87^{a}**	

Average or means with the same superscript letters within column indicate no significant difference (p <0.05)

The analysis of variance revealed significant differences ($p < 0.05$) on the particle size of the biomass and the amount of binding agent applied.

Energy Density. Table 5 shows the energy density of cacao pod husk based fuel briquettes. The highest and lowest energy density of cacao pod husk fuel briquettes obtained were 2,412.55±0.02 cal/ cc and 1,479.70±0.03 cal/cc, respectively. The energy density is directly proportional to the percent binding agent and inversely proportional to the particle size of cacao pod husk. The calorific value of cacao pod husk is 3,216.73 cal/g. The analysis of variance revealed significant differences ($p < 0.05$) on the particle size of the biomass and the amount of binding agent applied.

Optimum proportion of cacao pod husk fuel briquettes

The cacao pod husk based fuel briquettes with 10% binding agent and <2.2 mm particle size of pod husk exhibited the best formulation with bulk density, shatter resistance and break strength with a mean value of 0.75 g/cc, 99.93% and 0.114 kN, respectively.

Compressive Strength and Thermal Properties of Briquettes

The cacao pod husk based fuel briquettes had a compressive strength under axial pressure of 4.18 MPa. Likewise, the briquettes were easily burned with an ignition time of 1.8 min. It took 30 min to boil water. Moreover, the total time that completely turned the cacao pod husk briquettes into ash was 72 min. The computed thermal efficiency was 26.06%.

Energy Balance. The machines used in the briquetting of cacao pod husk based fuel briquettes were the shredder, hammer mill, mechanical mixer and briquetting machine. Sun drying method was used to dry shredded cacao pod husks and briquettes.

Table 6 shows the amount of energy needed to produce a ton of cacao pod husk briquettes. The energy demand of machine was 393.07 kWh or 96.06% of the total energy consumption. The preparation of binder obtained the highest energy with a value of 213 kWh. The energy demand in the production of a ton of briquettes was only 10.93% of the energy contained in a ton of cacao pod husk briquettes with a value of 3,741.1 kWh. The result was nearly comparable to the wood sawdust-based briquettes with a value of 4.37% (Gentil and Vale, 2015).

Table 6. Energy demand to produce one ton of cacao pod husk briquettes, kWh

Process	**Energy (kW)**			
	Machine	**Human (x10-5)**	**Total**	**Participation (%)**
Shredding	29.17	2.16	31.33	7.66
Drying	0	0.88	0.88	0.22
Hammer milling	6.67	0.1	6.77	1.65
Binder preparation	213	1.76	214.76	52.48
Mixing	22.99	1.7	24.69	6.03
Briquetting	121.24	8.97	130.21	31.82
Drying	0	0.55	0.55	0.13
Total	**393.07**	**16.12**	**409.19**	

CONCLUSION

The average weight of cacao pods was 588.27 grams. The K2 clone had the highest percentage of cacao pod husk with a value of 80.24%±1.82 followed by PBC123 (77.41%±1.19), BR25 (75.63%±3.11), K1 (73.99% ± 2.25) and UF18 (73.69%±3.99). The initial moisture content of pod husk ranged from 89.21%±1.27 to 90.10%±0.93. The combustible volatile matter and fixed carbon content of pod husk obtained ranges from 60.89% to 64.69% and 27.16% to 29.69%, respectively. Ten percent binding agent and less than 2.2 mm particle size of cacao pod husk obtained the highest bulk density, shatter resistance and break strength of fuel briquettes with a mean value of 0.75 g/cc, 99.93% and 0.114 kN, respectively. It was observed that the higher amount of binding agent and smaller particle size of cacao pod husk, the bulk density, shatter resistance and break strength of fuel briquettes increases.

The compressive strength, average energy density and thermal efficiency of the optimum formulation were 4.18 MPa, 2,412.55 cal/cc and 26%. It can be an alternative fuel to wood charcoal because the energy values and combustion qualities are sufficient to produce the required heat for domestic cooking and industrial applications. The energy demand in the production of a ton of briquettes was only 10.93% of the energy contained in a ton of cacao pod husk briquettes with a value of 3,741.1 kWh.

RECOMMENDATIONS

The establishment of village-type cacao pod husk briquetting plant in selected cacao producing areas is recommended.The pilot testing of the technology in selected cacao producing areas is also recommended to determine the specific technical, financial, operational and management requirements needed to operate the project as a village enterprise.

Likewise, this study recommends the extraction and utilization of liquid extract from cacao pod husk as fertilizer.

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MODELING THE ENERGY, YIELD AND INCOME OF SWEET POTATO PRODUCTION IN TARLAC, PHILIPPINES

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ABSTRACT

The energy use and the relationships between the energy inputs and yield as well as cost of inputs and income of sweet potato production in Tarlac, Philippines were analyzed. Data were collected from 180 farmers using structured survey questionnaires and face-to-face interviews. The total input and output energy of sweet potato production was 29326.78 and 53885.90 MJ ha-1, respectively. Chemical fertilizers and diesel fuel contributed the largest portion of the total energy consumption. The energy use efficiency, specific energy and energy productivity were 1.84, 1.95 MJ kg-1 and 0.51 kg MJ-1. Respectively, indirect and non-renewable forms of energy had the largest share of the total input energy. In addition, models were developed using the Cobb–Douglas production function and estimated the impact of energy inputs on yield as well as the cost inputs on income. There were significant and positive effects of diesel, machinery and chemical fertilizer energy on yield and costs on income indicating that at the present level of production practices, the increase use of diesel, machinery and chemical fertilizer would increase yield and income. It is further implied that the application of mechanization on labor-intensive and/or yield-augmenting operations would enhance farm productivity in the study area. Along with mechanization, the use of water-conserving practices and other renewable forms of energy should be considered to balance the GHG emissions and enhance the sustainability in sweet potato production.

Keywords: Econometric, Energy, Regression, Sensitivity analysis, Sweet potato

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INTRODUCTION

Sweet potato (Ipomoea batatas L) is one of the most important food crops grown worldwide with an annual production of 104,453,966.00 metric tons (FAO, 2016). It is the seventh most important food crop in the world. Because of its nutritional value, the demand for sweet potato in the fresh and process market is continuously increasing. Sweet potato is one of the substantial sources for starch, sugar, alcohol, flour and other industrial products (Lee et al, 2006; Adenuga, 2010). It is one of the energy crops like corn, cassava, sugarcane and sweet sorghum because of its potential source as feedstock for bioethanol production. With the current technology, about 12.5% of bioethanol can be recovered from processing of fresh sweet potatoes (Qiu et al. 2010).

In the Philippines, sweet potato is one of the most important cash crops due to its low input requirement. The average annual production of sweet potato in the country is 532,443 metric tons (BAS, 2014). The yield can be increased through varietal improvement, improved crop management practices as well as reduced postharvest losses.

Increasing the yield using high-yielding clean planting materials, chemical fertilizers and pesticides have been done by most farmers in the province of Tarlac. Tarlac is one of the top producing sweet potato provinces in the country and considered as the main supplier of sweet potato to the famous fruits and vegetables marketplace in the country, the "Divisoria market". Increasing the yield of sweet potato production also requires higher energy input both in production and postproduction operations.

Energy is one of the main elements in modern agriculture as it depends heavily on fossil and other energy resources. The increase in input energy to obtain maximum yields may not usually obtain high profits due to the increase also in the cost of production (Erdal et al. 2007). Effective use of energy in agriculture is one of the conditions for sustainable agricultural production since it helps to save financial resources, conserve fossil fuels and reduce air pollution (Pimentel, 1980). Therefore, it is imperative that energy must be used efficiently to achieve high productivity and at the same time ensure sustainable agriculture (Ozkan et al. 2007).

An assessment of the existing energy utilization and its effect on crop production is an activity to establish empirical data as bases for enhancing energy efficiency in crop production. Parametric methods such as Cobb-Douglas production function have been widely used to estimate relationships of energy on crop yield, cost and income for efficient resource allocation in agricultural crop production. Several studies have used this method and investigated the functional relationship between energy inputs and yield of stake tomato in Turkey (Erdal et al. 2009), greenhouse cucumber (Mohammadi and Omid, 2010), tamarind (Mohammadshirazi et al. 2012), pear (Tabatabaie et al. 2013), garlic (Samavatean et al. 2011), and apple (Rafiee et al. 2010) in Iran.

This study aimed to establishing the relationship between energy inputs and yield and production cost and net income in sweet potato production. This research was undertaken to establish empirical data for optimizing the required energy inputs and improving environmental aspects at various points in the entire sweet potato production.

METHODOLOGY

Sweet potato production system boundary

Sweet potato production system at the farm-level of operation (Figure 1) was evaluated. The pre-harvest operations included the crop cultivation and management while the postharvest operations considered were harvesting (vine removal and uprooting of tubers), in-field gathering, sorting and bagging and in-field hauling. In this study, the analysis started from production to farm gate boundary, which provided flexibility for analyzing different crops with various end uses (e.g., food, feed, fuel). Other on-farm processing beyond in-field hauling operation was not included because the sweet potato is sold as fresh tubers in the market.

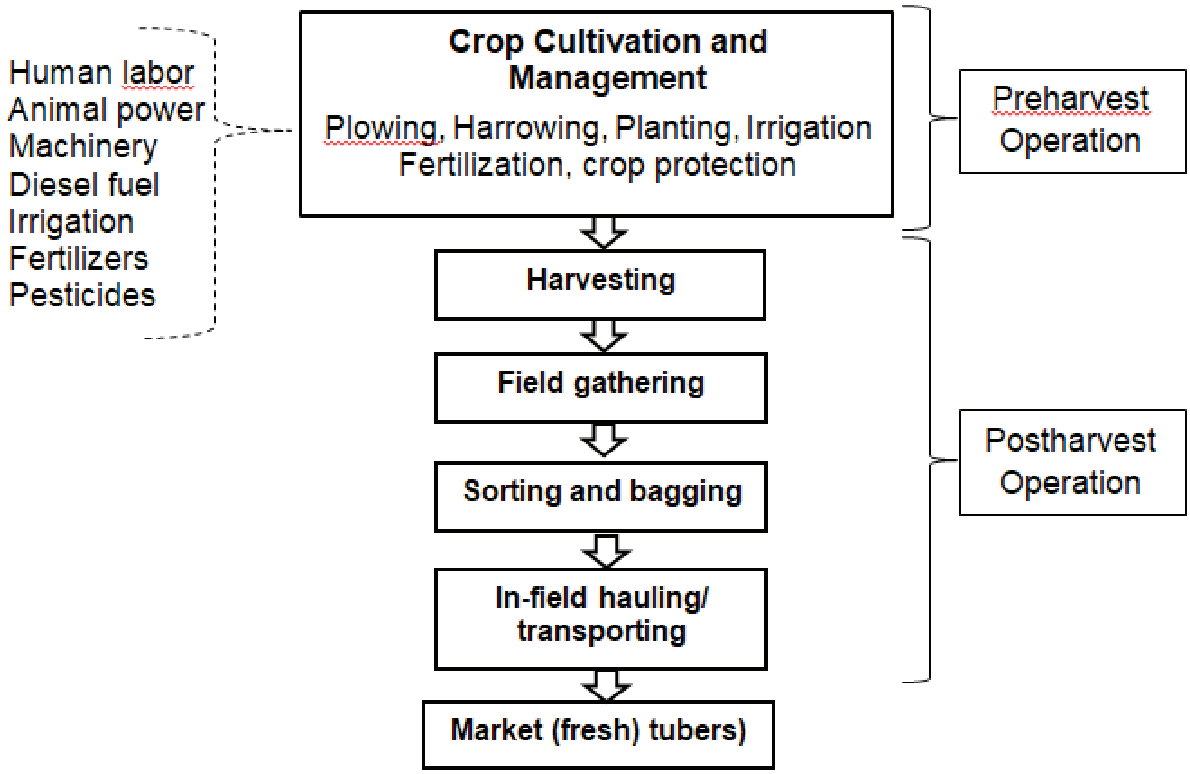

Figure 1. Sweet potato production system boundary; Tarlac Philippines; 2015

Data collection and analysis

Data were collected from 180 sweet potato farmers using structured survey form. The data were on production systems from land preparation, crop management, harvesting and in-field hauling of fresh sweet potato roots. The input requirements included planting materials, human labor, animal power, machinery, diesel fuel (used in land preparation, irrigation, harvesting and in-field hauling), fertilizers and pesticides for crop management while yield in fresh sweet potato tubers was specified as output. The sample size was determined using Equation 1 (Yamane, 1967).

$$n = \frac{N}{1+Ne^2} \qquad (1)$$

Where n is the required sample size; N, the number of sweet potato farmers in target population and e, the acceptable error (permissible error was chosen as 5%).

Assessment of energy input-output of sweet potato production

Human labor, animal power, machinery, diesel fuel, chemical fertilizers, chemical pesticides and irrigation were identified as inputs while the sweet potato roots in fresh form was considered the output. The amount of each input was multiplied with the energy coefficient equivalent as listed in Table 1 to calculate the energy use per hectare. Sweet potato farmers commonly used four-wheel tractors and other agricultural equipment for their land preparation, planting, harvesting and in-field hauling. Thus, the machinery energy input is calculated using equation 2 (Bautista and Minowa, 2010):

$$MIE = \frac{MEC \ x \ MW}{LM \ x \ EFC} \qquad (2)$$

Where MIE, is the machinery input energy in MJ ha-1, MEC is the machine energy coefficient at 108.9 MJ kg-1, MW is the machine weight in kg, LM is the life of machine at 9600 h and EFC is the effective field capacity of the machine or equipment in ha h-1.

The energy input was examined as direct and indirect, renewable and non-renewable forms of energy. Energy indicators such as energy ratio (ER), energy productivity (EP), specific energy (SE) and net energy (NE) were determined using equations 3 to 6, respectively (Yousefi et al., 2014).

$$ER = \frac{\textit{Energy output (MJ/ha)}}{\textit{Energy input (MJ/ha)}} \quad (3)$$

$$EP = \frac{\textit{Sweet potato roots output (kg/ ha)}}{\textit{Energy input (MJ/ha)}} \quad (4)$$

$$SE = \frac{\textit{Energy input (MJ/ ha)}}{\textit{Sweet potato roots output (kg/ha)}} \quad (5)$$

$$NE = \textit{Energy output (MJ/ha)} - \textit{Energy input (MJ/ha)} \quad (6)$$

Energy ratio is sometimes called EROI which means the energy return on energy investment (Andrea et al., 2014; Tieppo et al., 2014). It is an indicator to determine the productivity and efficiency of energy in the crop production system. It is indicated that a little portion of the input energy is utilized in the production process if the ratio is high.

On the other hand, most of the input energy is consumed to maintain the process if the ratio is low (Gagnon et al. 2009).

Table 1. Energy equivalent of inputs and output in sweet potato production system

Input/output	Unit	Energy (MJ unit-1)	Reference
A. Inputs			
1. Human labor	H	1.96	Mohammadi et al., 2010
2. Animal power	H	3.49	Pimentel, 1979
3. Machinery	kg	108.9	Pimentel, 1992, Kitani 1999
4. Diesel fuel	L	47.8	Pimentel, 1992, Kitani 1999, Esengun et al. 2006
5. Chemical Fertilizers			
a. Nitrogen (N)	kg	78.1	Kitani. 1999
b. Phosphorous (P2O5)	kg	17.4	Kitani. 1999
c. Potassium (K2O)	kg	13.7	Kitani. 1999
6. Chemical Pesticides			
a. Insecticides	kg	101.20	Ozkan et al. 2007
b. Herbicides	kg	238.00	Ozkan et al. 2007
c. Fungicides	kg	216.00	Ozkan et al. 2007
7. Water for irrigation	m^3	0.63	Hatirli et al. 2005
B. Output			
1. Sweet potato roots	kg	3.59	Oke et al. 2013

Analysis on the effect of energy inputs on yield of sweet potato production

In order to analyze the relationship between energy inputs and yield, Cobb-Douglas production function was used. Cobb-Douglas production function has been used by several authors to examine the relationship between energy inputs and yield (Mobtaker et al., 2010, Rafiee et al., 2010, Erdal et. al., 2009; Hatirli et al., 2006). In this study, the Cobb-Douglas production function was used and expressed in equation (7).

$$Y = f(X) \exp(u) \qquad (7)$$

Where Y is the yield and u is the energy value of each input. Equation (8) can be linearized and expressed in equation (6).

$$\ln Y_i = a_0 + \sum_{j=1}^{n} a_j + \ln(X_{ij}) + e_i,\ i = 1,2,3, \qquad (8)$$

Where Yi denotes the yield level of the i'th farmer, X_{ij} is the vector inputs used in the production process, a_0 is the constant term, a_j represents coefficients of inputs which are estimated from the model and e_i is the error term. It is assumed that if there is no input energy, the output energy is also zero. Making this assumption removes the constant term a_0 from Eq. (7), and reduces to equation (9).

$$\ln Y_i = \sum_{j=1}^{n} a_j + \ln(X_{ij}) + e_i \qquad (9)$$

The equation 7 was expanded in accordance with the assumption that yield is a function of energy inputs and can be expressed as equation 10.

$$\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 \ldots + \alpha_7 \ln X_7 + e_1 \ldots. \qquad (10)$$

Where Yi denotes the yield level of the i'th farmer, Xij is the vector inputs used in the production process that stands for energy of diesel (X_1), machinery (X_2), animal (X_3), human labor (X_4), Irrigation (X_5), chemical fertilizer (X_6), and chemical pesticide (X_7).

Similarly, the effects of direct, indirect, renewable and non- renewable energies on yield were investigated using the following equations (11) and (12).

$$\ln Y_i = \beta_1 \ln(DE) + \beta_2 \ln(IDE) + e_1 \qquad (11)$$

$$\ln Y_i = \gamma_1 \ln(RE) + \gamma_2 \ln(NRE) + e_1 \qquad (12)$$

Where Yi is the i'th farmer's yield, DE, IDE, RE and NRE are direct, indirect, renewable and non-renewable energies, respectively used in production; β_i and γ_i are coefficients of exogenous variables and e_i is the error term.

Analysis on the effect of cost of inputs on income of sweet potato production

In addition to the effect of different input energy on the yield level, the impact of input expenses on net income was investigated. Similarly, the Cobb–Douglas production function was used in the following form, expressed in equation (13).

$$\ln Y'_i = \alpha'_1 \ln X'_1 + \alpha'_2 \ln X'_2 + \alpha'_3 \ln X'_3 + \alpha'_4 \ln X'_4 + \ldots + \alpha'_7 \ln X'_7 + e_1 \ \ldots\ldots\ldots\ldots \qquad (13)$$

Where Y_i is the i'th net income, and α'_i is the coefficient of exogenous variables. X'_{ij} is the vector inputs used in the production process that stands for cost of human labor (X'_1), machinery (X'_2), diesel fuel (X'_3), chemical fertilizers (X'_4), farmyard manure (X'5), chemical pesticides (X'_6), water for irrigation (X'_7) and electricity (X'_8). Coefficients of equations 10 to 13 were estimated using ordinary least square (OLS) technique in IBM SPSS Version 23.

Sensitivity analysis of inputs (energy or production cost) was done based on the response coefficients of inputs by use of marginal physical productivity (MPP). The MPP of a factor indicates the change in output with a unit change in factor input in question, keeping all other factors constant at their geometric mean level. The MPP can be calculated by using equation 14 (Singh et al., 2004).

$$MPP_{xj} = \frac{GM\,(Y)}{GM(X_{xj})} \times a_{ij} \qquad (14)$$

Where MPP xj is the marginal physical productivity of the jth input, a_{ij} is the regression coefficient of the jth input. GM (Y), geometric mean of the output yield or income and GM_{xj}, geometric mean of the jth input (energy or cost). A positive value of MPP of any factor implies that the total output is increasing with an increase in input. A negative value of MPP of any factor implies that supplementary units of inputs are participating negatively to production (less production with more input).

RESULTS AND DISCUSSION

Analysis on the energy input-output of sweet potato production

The inputs used and output in sweet potato production system in Tarlac with their energy equivalents are summarized in Table 2. The average sweet potato yield was 15,010 kg ha-1 with an equivalent energy output of 53,885.90 $MJha^{-1}$. The total energy input in sweet potato production was 29,326.86 $MJha^{-1}$ resulting in a net energy of 24,559.04 $MJha^{-1}$. Figure 2 displays the distribution of energy inputs in sweet potato production. As depicted, majority of the total input were contributed by nitrogen fertilizer (50.86 %) followed by diesel fuel (34.31%) and irrigation water (6.53%). Similar results were observed in the production of other agricultural crops such as sugar beet (Asgharipour et al. 2012), Irish potato (Pishgar-Komleh et al. 2012), wheat (Singh et al. 2007) and corn (Yousefi et al. 2014b) where chemical fertilizer, specifically nitrogen is the highest contributor of energy to the total input energy of crop production. The energy consumed for each operation in the agricultural production system of sweet potato is presented in Table 3. It is evident that preharvest operations consumed most of the energy at 26327.33 $MJha_{-1}$, giving 89.77 % share of the total input energy.

Meanwhile, postharvest operation utilized 2,999.45 MJha-1 or 10.23% of the total input energy of sweet potato production. Among all operations, the application of fertilizers provided the highest share of utilized energy with 51.71%, followed by irrigation (24.28%) and land preparation (11.05%). The high energy utilized on the afore-mentioned operations could be due to the excessive use of nitrogen in the application of fertilizers and inefficient irrigation method consuming more diesel fuel.

Table 2. Energy inputs and output of sweet potato production; Tarlac, Philippines; 2015

Input/output	Quantity per unit area (ha)	Total energy equivalent (MJ ha-1)	Standard Deviation
A. Input			
1. Diesel	210.47 L	10060.77	626.91
2. Machinery	14.04 H	477.78	69.89
3. Animal labor	32.00 H	111.68	3.83
4. Human labor	726.00 H	1422.96	7.53
5. Irrigation water	3042.0 m_3	1916.46	61.63
6. Chemical fertilizers			
Nitrogen –N	191.00 kg	14917.10	3046.02
Phosphate- P2O5	7.00 kg	121.80	25.15
Potassium – K2O	7.00 kg	95.90	19.76
7. Chemical pesticides	2.0 kg	202.40	49.02
Total Input		29326.86	3805.54
B. Output			
Sweet potato roots	15010 kg	53885.90	16404.87
C. Net Energy		24559.04	12974.64

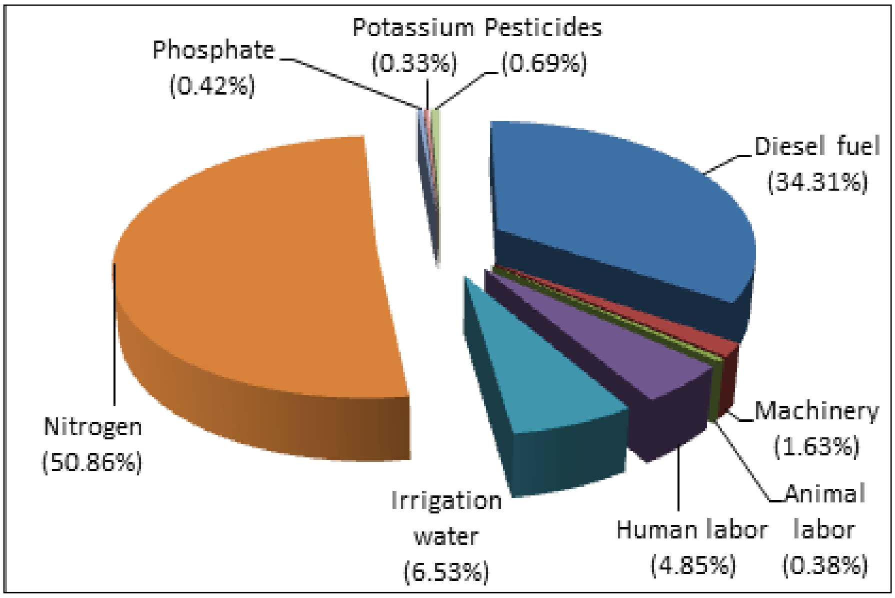

Figure 2. Distribution of energy inputs for sweet potato production; Tarlac, Philippines; 2015

Table 3. Energy inputs per operation of sweet potato production; Tarlac, Philippines; 2015

Operation	Total energy equivalent (MJha-1)	Energy Share (%)
Preharvest operation	***26327.41***	***89.77***
1. Land preparation	3241.07	11.05
2. Planting materials	156.80	0.53
3. Transplanting	235.20	0.80
4. Irrigation	7120.02	24.28
5. Fertilizer application	15166.16	51.71
6. Pesticide application	233.76	0.80
7. Side dressing/hilling-up	174.40	0.59
Postharvest operation	***2999.45***	***10.23***
8. Harvesting	1459.44	4.98
9. Field gathering	235.20	0.80
10. Sorting and bagging	156.80	0.53
11. In-field hauling	1148.01	3.91
Total Input	**29326.86**	**100.00**

Table 4. Indicators of energy use in sweet potato production

Indicators	Unit	Quantity
Inputs Energy	MJ ha^{-1}	29326.78
Output Energy	MJ ha^{-1}	53435.60
Energy ratio		1.84
Energy Productivity	kg MJ^{-1}	0.51
Specific Energy	MJ kg^{-1}	1.95
Net Energy	MJ ha^{-1}	24559.12

Energy indicators such as energy ratio, energy productivity, specific energy and net energy in sweet potato production are enumerated in Table 4. Energy ratio is generally used as an index to assess the efficiency of energy in crop production systems. Thus, the higher the energy ratio, the more efficient use of energy is attained in crop production. Efficient use of energy resources is vital in terms of increasing production, productivity and competitiveness in agriculture as well as sustainability (Hatirli et al. 2006) of crop production systems.

The energy ratio calculated for sweet potato production was 1.84. This implied that the energy consumed in the production process has been replenished 1.84 times by the energy produced from harvested sweet potato roots. With this, the calculated specific energy value and energy productivity was 1.95 MJ kg^{-1} and 0.51 kg MJ^{-1}, respectively.

This means that an input energy of 1.95 MJ is needed to yield one kilogram of sweet potato or 0.51 kg of sweet potato roots is produced per unit (MJ) input energy. Currently, there is limited or perhaps no studies on energy generated for sweet potato production. However, in some related studies, the value of energy ratio for potato of 1.71 (Pishgar-Komleh et al. 2012), 1.14 and 0.95 (Zangeneh et al., 2010), and 1.25 (Mohammadi et al. 2008) were close to energy ratio generated in this study (1.84).

The forms of energy in sweet potato production can be distributed into direct and indirect or renewable and non-renewable energies as presented in Table 5. Indirect energy share of 53.93% dominated the direct energy share of 46.07% of the total input energy consumption for sweet potato production. The high indirect energy was attributed to the use of inputs such as chemical fertilizers and machinery. Majority of the total input energy share in the area of the study was non-renewable energy at 88.23% while the remaining renewable energy input was 11.77%. The use of non-renewable energy sources would result in to fast exploitation of fossil fuel reserves which cannot be replaceable.

Thus, to control the high rate of non-renewable energy consumption, renewable energy should be considered because they are naturally available and replaceable.

Based on the results, the level of dependence to non-renewable form of energy was generally high. This is mainly contributed by the large amount of chemical fertilizers and diesel fuel used in sweet potato production. The lahar-laden areas planted to sweet potato in Tarlac needed frequent irrigation using mechanical pumps.

In addition, the relatively low fertility of the soil required higher amounts of chemical fertilizer. It is expected that in modern agriculture production system, the use of non-renewable energy is greater than renewable energy. Apparently, low input sustainable crop production is more efficient than conventional production and far more efficient when organic farming is employed due to non-utilization of any agrochemical inputs (Mendoza, 2005).

Practices that will conserve fossil resources and promote sustainable agriculture are encouraged such as the use of organic mulch to conserve water and reduce the frequency of irrigation; better water management technique like using hose for water delivery instead of unlined canals; soil amelioration to improve soil structure to improve fertility and water holding capacity and; the use of renewable input resources like home-made organic foliar fertilizers instead of chemical fertilizers.

Table 5. Total energy input in form of direct, indirect, renewable and non-renewable for sweet potato production

Indicators	Quantity (MJ ha-1)	Percent share (%)
Direct Energy[a]	13511.78	46.07
Indirect Energy[b]	15815.00	53.93
Renewable Energy[c]	3451.10	11.77
Non-renewable Energy[d]	25875.68	88.23
Total Energy Input	29326.78	100.00

[a]*Includes human labor, animal labor, diesel, irrigation water*
[b]*Includes machinery, planting materials, chemical fertilizers, chemical pesticides*
[c]*Includes human labor, animal labor, planting materials*
[d]*Includes diesel, chemical fertilizers, chemical pesticides, machinery*

Table 6. Econometric estimation results of energy inputs

Endogenous variable: Yield	Coefficient	t-stat	MPP
Model 1: $lnY_i = \alpha_1 \, lnX_1 + \alpha_2 \, lnX_2 + \alpha_3 \, lnX_3 + \alpha_4 \, lnX_4 + \alpha_5 \, lnX_5 + \alpha_6 \, lnX_6 + \alpha_7 \, lnX_7 + e_1$			
Exogenous variables			
X_1 Diesel	1.95	6.22**	2.03
X_2 Machinery	0.60	3.95**	0.93
X_3 Animal power	0.37	2.45*	0.74
X_4 Human labor	2.53	0.97ns	3.33
X_5 Irrigation water	0.61	2.51*	0.77
X_6 Chemical fertilizer	0.35	4.84**	0.35
X_7 Chemical pesticide	-0.09	-3.22**	-0.17
Coefficient of determination,R^2	0.96		
Return to scale(RS)	6.31		

Econometric model estimation of energy inputs on yield of SP production

The relationship between the energy inputs and yield was estimated using Cobb-Douglas production function and analyzed using ordinary least square estimation. Sweet potato yield was assumed to be a function of diesel fuel, machinery, animal power, human labor, irrigation water, chemical fertilizers and pesticides. Results of the analysis showed that the coefficient of determination (R2) for this model was 0.96 (Table 6) implying that 96 % of the variations in yield could be explained by the variables included in the model.

Five variables were found to have significant and positive influence on yield, namely: diesel fuel, machinery, chemical fertilizer, irrigation water and animal power.

The contribution of diesel fuel, machinery, chemical fertilizer and chemical pesticide was significant (P<0.01). These imply that an additional use of 1% for each of these inputs would lead respectively to 1.95, 0.60 and 0.35% increase in sweet potato yield. These results suggested that mechanizing the production of sweet potato would lead to increase productivity.

On the other hand, chemical pesticide had a significant but negative influence on yield of sweet potato in Tarlac. One of the problems of sweet potato farmers was the source of clean planting material. Disease-infected planting material significantly reduced their yields and that no amount of chemical spraying could control the disease once it has set in. Another pest of sweet potato which was difficult to control was the weevil which attacks while the roots are still in the soil.

Other exogenous factors that significantly contribute at 5% level are the irrigation water and animal power. The coefficient of animal power and irrigation water energies was estimated as 0.61 and 0.37, respectively (P<0.05). The sum of the regression coefficients or returns to scale (RTS) of the energy inputs was calculated at 6.31 for Model I. This implied that a 1% increase in the total energy inputs would lead to 6.31% increase in sweet potato yield.

The sensitivity of energy inputs on production yield was determined using the MPP procedure based on response coefficient of inputs. Among the variables, diesel had the strongest influence on yield followed by machinery and chemical fertilizer. Results indicated that additional utilization of 1 MJ of diesel fuel, machinery and chemical fertilizer would result in an increase in yield of 2.03, 0.93 and 0.35 kg ha-1, respectively showing that these exogenous factors have high significant impacts on the yield (endogenous variable). Other factors that significantly influenced yield at 5% level were irrigation water and animal power.

Diesel and machinery are energy inputs used in land cultivation, ridging and weeding during planting and crop management. On the other hand, chemical fertilizer and water for irrigation are both factors used to enhance and improve yield.

The relationships between DE and IDE, as well as RE and NRE on yield were analyzed using Models II and III (Table 7). Both the R^2 were high at 0.94 and 0.93 for Model II and III with DE and IDE and RE and NRE, respectively. These imply that the variations in yield could be explained by the variables included in the models. Regression coefficients of IDE, DE, NRE and RE were positive and significant (P<0.01). DE had higher coefficient (3.80) than IDE (0.51) while RE had higher coefficient (2.89) than NRE (1.79). These indicate that impact of DE and RE on yield was more than that of IDE and NRE. RTS (returns to scale) values for Models II and III were found to be 4.32 and 4.21 respectively.

Table 7. Econometric estimation results of different forms of energy

Endogenous variable: Yield	**Coefficient**	**t-stat**	**MPP**
Model 2: $lnY_i=\beta_1\ ln(DE) + \beta_2\ ln(IDE) + e_1$			
Exogenous variables			
DE- Direct energy	3.80	11.38**	3.82
IDE- Indirect energy	0.51	6.70**	0.51
Coefficient of determination, R^2	0.94		
Return to scale(RS)	4.32		
Model 3: $lnY_i=\beta_1\ ln(RE) + \beta_2\ ln(NRE) + e_1$			
Exogenous variables			
RE- Renewable	2.49	6.18**	2.93
NRE- Non-renewable	1.72	33.84**	1.62
Coefficient of determination, R^2	0.93		
Return to scale(RS)	4.21		

*Significant at 5% level; ** Significant at 1% level, ns non-significant

The values of MPP for DE and IDE were 3.82 and 0.51, respectively. As indicated, direct energies such as diesel and water for irrigation and indirect energies such as machinery and chemical fertilizers were estimated to have significant impacts on sweet potato yield. Also, the MPP values for RE and NRE were 2.93 and 1.62, respectively, indicating that an additional use of 1 MJ of each of these energy forms would lead to an additional increase in yield by 2.93 and 1.62 kg ha-1.

Econometric model estimation of cost inputs on net income of SP production

The costs of each input used and calculated gross production values for sweet potato are summarized in Table 8. The mean gross value (income) of production (PhP 150,100 ha^{-1}) was obtained, given a yield of 15,010 kg ha^{-1} and selling price of PhP10.00 kg^{-1}. The total mean cost of production was PhP 66,781.33 ha^{-1} and a net income of PhP 83318.67 ha^{-1}.

Figure 3 depicted the percentage share of each input cost based on the total expenditures. Among the inputs, the human labor expense had the highest share of 27% which was spent mostly in all the operations such as land preparation, planting, fertilizer and pesticide application, harvesting, packaging and in-field hauling. Other expenses were planting material (21%), chemical fertilizer (17%) and machinery expenses (17%).

The cost of planting materials was high because sweet potato farmers opted to purchase it from other provinces that grow clean planting materials (CPM) with high resistance to pest and diseases (weevil infestation).

The regression coefficients of cost on net income were analyzed and presented in Table 9. Among the variables included in the study, diesel, machine, chemical fertilizer and planting materials were found to significantly influence net income ($P<0.01$). A 1% change on each of the expense on diesel, machine, chemical fertilizer and planting material expenses would result to 4.04, 1.44, 0.60 and -0.60, respectively implying that for a given 1% change of each of these inputs would result in 4.04, 1.44, 0.60% increase and 0.60 decrease in income, respectively.

Table 8. Cost and return analysis of sweet potato production; Tarlac, Philippines; 2015

Cost and return components	**Unit**	**Mean value**	**STDEV**
Yield	Kg	15010.00	4569.60
Gross income	PhP ha^{-1}	150100.00	45696.02
Total production cost	PhP ha^{-1}	66781.33	5234.55
Diesel fuel expense	PhP ha^{-1}	6735.11	420.00
Machinery expense	PhP ha^{-1}	11430.25	1671.90
Animal labor expense	PhP ha^{-1}	2398.75	80.64
Human labor expense	PhP ha^{-1}	18150.00	96.01
Planting material expense	PhP ha^{-1}	14277.78	1210.09
Chemical fertilizer expense	PhP ha^{-1}	11389.44	1920.68
Chemical pesticide expense	PhP ha^{-1}	2400.00	581.27
Net income	PhP ha^{-1}	83318.67	40989.47

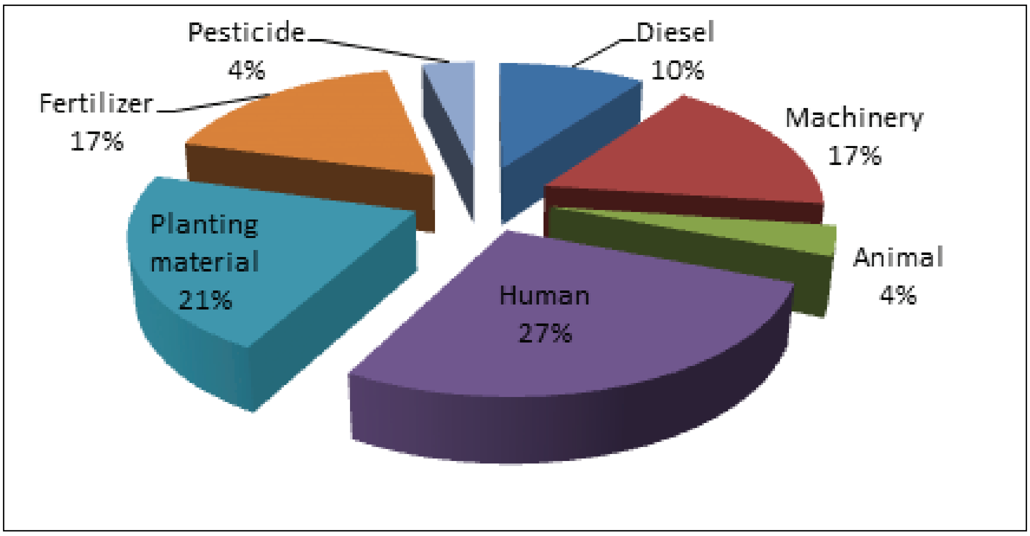

Figure 3. Percentage share of cost inputs in SP production; Tarlac, Philippines; 2015

The other important input was chemical pesticide with an elasticity of -0.13 (P<0.05). While the expenses on diesel, machines and chemical fertilizers were found to positively influence income, the expenses on planting material and chemical pesticide gave negative trends. The positive response of net income to increasing expenses on diesel, machines and chemical fertilizers could be explained by the positive response of yield to these inputs indicating that the benefits from their applications are still higher than the costs. The reverse trend on income occurred on planting material and pesticide costs. Yield is relatively influenced by pesticide as the disease and insect pest of sweet potato are difficult to control and could reduce the quantity and value of yield significantly.

The results showed similar trend when compared to energy inputs and yield relationship using model 1. Among the cost inputs, diesel fuel had the highest positive elasticity followed by machinery and chemical fertilizer. This result indicated that mechanization could still enhance yield and income in SP farming. However, the use of renewable forms of energy such as biodiesel and non-chemical derived fertilizer should be encouraged and considered to balance the GHG emissions during mechanization process.

The use of diesel fuel is related to the use of machines in sweet potato farming. These inputs were used during land preparation, cultivation, planting, irrigation, harvesting and in-field hauling of harvested sweet potato. Chemical fertilizers were used to improve soil fertility to increase yield and income. The sum of the regression coefficients or return to scale (RTS) of the cost inputs was calculated as 8.08 for Model 4. This implies that a 1% increase in the total cost inputs would lead to 8.08 % increase in net income of SP production.

The sensitivity analysis indicated that highest MPP was estimated for diesel fuel (5.12), followed by machinery (1.73), chemical fertilizer (0.72), planting material (-0.70) and chemical pesticide (-0.19). These results indicated that additional use of PhP 1.00 for each of these inputs would result in an increase by 5.12, 1.73, 0.70, and decrease by Php 0.70, respectively indicating that these factors have significant impact on the net income for sweet potato production.

Table 9. Econometric estimation results of cost inputs

Endogenous variable: Yield	Coefficient	t-stat	MPP
Model 4: $lnY'_i = \alpha'_1\ lnX'_1 + \alpha'_2\ lnX'_2 + \alpha'_3\ lnX'_3 + \alpha'_4\ lnX'_4 + \alpha'_5 lnX,_5 \ldots + \alpha'_7\ lnX'_7 + e_1$			
Exogenous variables			
X'_1 Diesel expense	4.04	7.60**	5.12
X'_2 Machinery expense	1.44	6.02**	1.73
X'_3 Animal power expense	0.04	0.14	0.06
X'_4 Human labor expense	2.69	0.55	3.07
X'_5 Planting material expense	-0.60	-3.59**	-0.70
X'_6 Chemical fertilizer expense	0.60	4.87**	0.72
X'_7 Chemical pesticide expense	-0.13	-2.52*	-0.19
Coefficient of determination, R^2	0.96		
Return to scale(RS)	8.08		

*Significant at 5% level; ** Significant at 1% level, ns non-significant

CONCLUSION AND RECOMMENDATIONS

Following the current production practices, the total energy consumed in producing sweet potato was 29326.86 MJha-1. Most of the energy inputs were contributed by chemical fertilizer (51.71%) and diesel fuel (34.31%) making the production of sweet potato largely dependent on non-renewable form of energy (88.23%). The use of diesel fuel, machines and chemical fertilizers significantly and positively influenced yield and income derived from sweet potato.

At the present production practices, mechanization proved to be an important input in sweet potato production to increase yield and income. The use however of renewable forms of energy such as biodiesel and non-chemical derived fertilizers should be encouraged to balance the GHG emissions during mechanization process. To maintain and enhance the sustainability of sweet potato production, it is necessary to check the use of chemical inputs and non-renewable energy resources. Crop rotation with nitrogen (N)-stabilizer plants such as leguminous plants can be considered to reduce inorganic N fertilizer consumption. The use of green manure or organic fertilizer instead of chemical fertilizer should be considered to control the high rate of non-renewable energy utilization.

Further study on determining relationship of inputs costs on net income can be done using normalized profit function. Optimization study can also be done to analyze the amount of energy and cost inputs that could maximize productivity. This will validate whether the existing level of energy inputs are enough to increase farm productivity and further conserve input energy and cost without affecting productivity. Furthermore, optimization study can determine inefficiency in crop farming such as wasteful utilization of input resources. With such information, the necessary amount of inputs to be used in order to attain efficient and sustainable crop production can be recommended.

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ASSESSMENT OF THE POSTHARVEST SYSTEMS AND LOSSES OF BULB ONIONS IN NUEVA ECIJA, PHILIPPINES

Gigi B. Calica[1] and Zeren Lucky L. Cabanayan[2]

ABSTRACT

Maintaining a supply of onion in the country has been a struggle for the past few years. Fluctuations in the supply may be attributed to a number of factors such as occurence of natural calamities, lack of farming motivation, less systematic commodity flow and production to postproduction lapses. To give the government relevant data in crafting policies for upgrading bulb onion industry, this study was conducted. The study aimed to establish the different postharvest systems and losses and to identify relevant mechanization intervention for the bulb onion industry in the Philippines. Case studies, Focus Group Discussion and survey were employed to collect data and were analysed using descriptive analysis.

Postharvest practices of producing bulb onions were laborious and manually done. Results revealed that the industry was incurring postharvest physical losses of 31.49% and quality losses of 32.41%. Potential interventions like the development of small-scale onion harvester, mechanical leaf cutter and modification and adoption of foreign technologies for local use to address problems on the timeliness, insufficient manpower supply and high postharvest losses should be investigated. Curing methods and technologies to extend storage shelf-life must be further studied. Training courses on best practices or GAP and on postharvest and mechanization should be extended.

Keywords: Bulb onions, Intervention, Mechanization, Postharvest losses, Postharvest systems

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INTRODUCTION

Onion is one of the important condiments widely used in all households all year round. The green leaves, and the immature and mature bulbs are eaten raw or used in preparation of meals. Onions are used in soups, sauces and for seasoning foods. The small bulbs one pickled in vinegar. Recent research has suggested that onions in the diet may play a part in preventing heart disease and other ailments. Onion bulb is rich in phosphorus, calcium and carbohydrates. The pungency in onion is due to a volatile oil known as allyl-propyl disulphide.

In the Philippines, bulb onion, locally known as "sibuyas", is probably the most indispensable culinary ingredient in the country. It is a favorite seasoning and its pungent aroma and sharp taste makes it ideal for spicing up meat, salads and vegetable dishes. For a country whose people are indulged in tasty and aromatic foods like the Philippines, the spice industry plays a very vital role. Bulb onions (Red Creole and Yellow Granex) are grown from seed while shallots are raised from bulbs which produce multiple shoots, each of which forms a bulb.

Maintaining a stable production trend of onion in the country had been a struggle for the past few years. Fluctuations in the supply may be attributed to a number of factors such as occurence of natural calamities, lack of farming motivation, less systematic commodity flow and production to postproduction lapses.

In the year 2012, despite allocation of larger hectarage for onion farming, yield was lowest for the past five years. This was due to occurence of strong typhoons and increased incidence of smuggling that hurt the onion industry (Figure 1).

The Bureau of Agiculture Statistics (2012) disclosed that onion production continued to decline by 12%. One of the major culprits was the onion importation that prevents the local farmers from planting. A study of the Bureau of Agricultural Reseach (BAR) revealed that farmers' practices, problems, and challenges did not change much over the years.

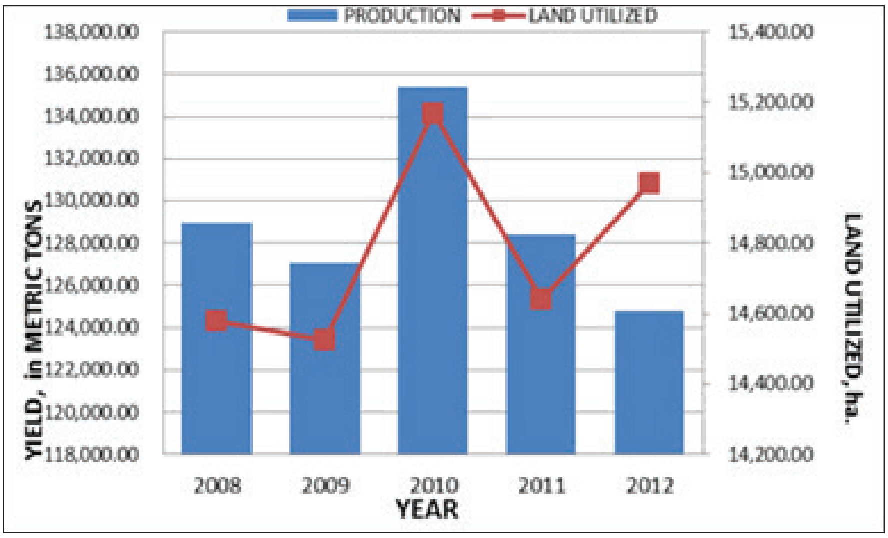


Figure 1. Onion production and land utilization in the Philippines, 2008-2012

Lean and Peak Production

The peak season of red bulb onion starts from January to April in Pangasinan, March to April in Nueva Vizcaya, Nueva Ecija and Occidental Mindoro. On the other hand, lean months start from December to February (Table 1).

Yellow Granex has short peak season in March in Pangasinan and April in Nueva Ecija. Unlike the red bulb, Yellow Granex has longer lean months which start from December to March for Pangasinan and Nueva Ecija (Table 2).

Proper postharvest handling and storgae starts with harvesting at maturity. The onions' neck should be thin or small, because the neck serves as passageway for gases and microorganisms. Thick necks would mean prove to easy deterioration.

Yellow onions have a very short dormancy period of (1-4 months) while red onions have four to six months. The dormancy period can be prolonged by proper storage. Damaged root plate or stem base and removal of the papery scales hasten the sprouting and softening of the bulbs in storage.

Topping (cutting of the leaves) and proper curing (drying the scales and neck) should be done for long storage life. Topping is cutting the leaves up to 2 to 3 cm above the neck.

The study generally aimed to establish the different postharvest systems with corresponding losses and identify relevant mechanization interventions for the bulb onion industry in the Philippines.

Specifically, it aimed to:
1. Identified and document the different practices/systems of bulb onions from the farm to the market.
2. Established the postharvest losses incurred from the postharvest systems of bulb onion industry;
3. Identified the constraints and problems that affect the distribution of bulb onions; and
4. Recommended potential interventions that could improve the handling of bulb onions.

Table 1. Harvesting calendar of red bulb onions

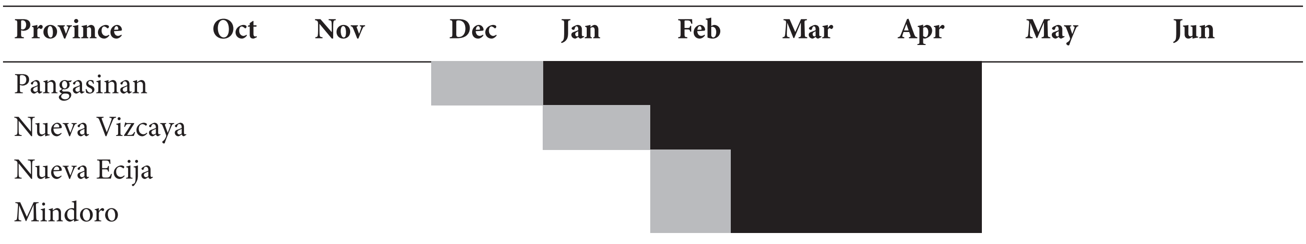
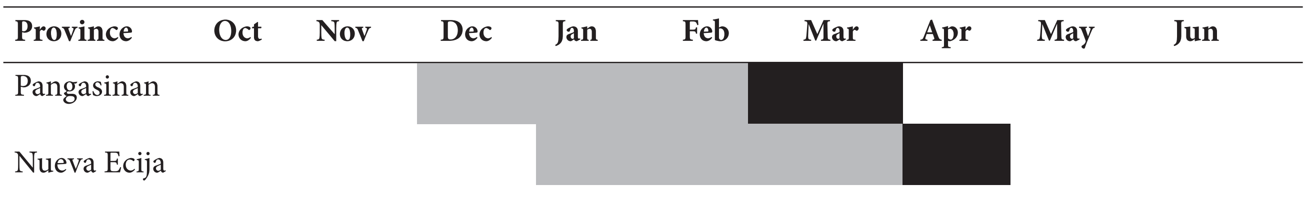


Table 2. Harvesting calendar of yellow bulb onions



Legend:

Peak season
Lean Season

Source: Provincial agriculturist offices

METHODOLOGY

Conceptual Framework

The project adapted the value chain framework using the Value Chain Diagnostic for Industrial Development by the United Nations Industrial Development Organization (UNIDO) 2010. Under given conditions, it permits understanding on how the industry operate and coordinate to ensure that primary materials are transformed, stored, transported and reach end-consumers in certain form and quality. Value chain diagnostics look at the existing constraints and opportunities to value chain development, which are multiple in nature. It also looks at the various effects that operations in the chain have on groups of people, e.g., with regard to poverty reduction, employment, income generation, economic growth, or environmental sustainability.

Study Sites and Data Collection

Study areas were Bongabon and San Jose of Nueva Ecija, the identified top bulb onion producing municipalities in the Philippines.

Key informant interviews such as the local government officials, provincial and municipal agriculturists, traders as well as group leaders knowledgeable on bulb onion production and marketing were tapped to identify the issues, problems and other necessary information regarding bulb onion production, handling and marketing.

Focus group discussions with the bulb onion farmers, agents and traders were conducted to understand the market chains of selling bulb onions in the local market. The major postharvest practices (i.e., farm to the market) identified in the FGDs were adapted for the case studies.

Case studies were conducted to document the current postharvest practices of the different stakeholders involved. Alongside with the documentation, measurement of the actual quantitative and qualitative losses incurred at each level of marketing chain and their possible causes were likewise done.

Site visitations of the identified existing facilities and technologies for bulb onion were also conducted.

Information gathered were processed and analyzed qualitatively. Potential interventions were proposed to improve the current industry.

Sampling Procedures and Sampling Size

Postharvest losses were measured quantitatively and qualitatively using the procedure developed by Maranan et al in 1996 and the BPRE and PHTRC in 2009.

1. 10 2mx2m sampling strings were randomly placed in the area to serve as sample areas.
2. Plants within the every sampling area were harvested manually. Harvested, unharvested, rotten bulb onions were collected and placed in sacks or plastic bags separately.
3. Harvested bulb onions in every sampling area were weighed as well as the unharvested and rotten bulb onions. Weights of these samples were recorded separately and tagged for identification.
4. The lot of bulb onions harvest as well as the bulb onion samples were transported to the trader's warehouse

Samples were transported to the cold storage for monthly monitoring on the quality and weight loss up to seven months.

Loss Measurements

The market chains observed for the conduct of loss measurement were the chains from the farmer/grower to local market and cold storage.

Two sets of cooperators each for the local market (red and yellow bulb) were identified. One chain of red bulb was extended to the cold storage which was observed and monitored for seven months.

Selection of cooperators was primarily based on the willingness of the different actors of the particular chain to allow the project team to conduct the handling trials while they were doing their respective marketing activities in the chain.

At each step of the route, the operations were observed, quality and losses (nature and extent, whenever possible) of the commodity were documented.

Quality loss on transport conditions like the road system, vehicles used, distance from farm to market, and time involved from point to point were noted.

Methods of Analysis

Quantitative/Weight Loss. The initial weight at the farm of the total volume marketed and the samples were noted. Final weight of the samples marketed at the wholesale level was also measured. At the farmer level, samples were returned to the lot after the quantitative analysis.

The commodity marketed by the farmer-cooperator was followed through by the team until it reached the first trader level. The same procedure for quantitative/weight loss at each trader level was done for each handling point until the commodity reached the retail level.

The information on the actual loss measurement was used not only to measure losses but also to identify what improved practices and/or technology intervention are needed to improve in the system.

Quantitative/weight loss was computed using the following formula:

$$\% \text{ weight loss} = \frac{wi-wf}{wi} 100 \qquad (1)$$

Where:

Wf = final weight of the sample/commodity at each handling point

Wi = initial weight of the sample/commodity at each handling point

Harvesting loss. After harvesting, the research team carefully collected the un-harvested produced left in the field whether intentional or not, but which the farmer did not collect. These products were left out, by-passed, shattered or have fallen on the ground by the harvesters. After collection, weighing the commodity was done to estimate the harvesting loss using the prescribed formula.

Harvesting loss (HL) =

$$\frac{\textit{Ave.wt of samples}}{m2} \text{ x } \frac{10{,}000m2}{ha} \qquad (2)$$

Harvesting loss (%HL)=

$$\frac{\textit{harvesting loss, kg}}{\textit{potential yield, kg}} \; x\ 100 \qquad (3)$$

Piling Loss. Underlays such as plastic sheets or canvas were laid on the spot where the farmers or traders piled their harvested products while waiting for the next activity. If the farmer or trader is using underlay, the project team placed their underlay beneath and outside those of the farmers so the produce that were scattered beyond the farmers' were taken as losses. After piling, all the produce that were left and were not recovered or totally ignored by the farmer were manually picked and weighed.

Piling loss (%PL) =

$$\frac{\textit{total weight piling loss, kg}}{PY(1\text{-}\%\textit{harvest loss})} \; x\ 100 \qquad (4)$$

Storage loss. After sorting, stocks were weighed (for initial weight) before transporting to the cold storage. Monthly monitoring of stocks was performed taking note of the weight, quality of the onions, and the temperature of the cold room. Monitoring started after a month the onions were inside the cold storage and lasted up to seven months.

Storage loss = %SL

Every month the samples were sorted for rotten and sprouted, weighed each classification and note the total weight.

The following formulas were used in the computation of the percentage of each category from the total sample.

$$\%\text{Sprouting} = \frac{\text{sprouted, kg}}{\text{weight/month}} \times 100 \qquad (5)$$

$$\%\text{Rotten} = \frac{rotten,kg}{weight/month} \times 100 \qquad (6)$$

$$\%\text{Weight loss} = \frac{weight/month\ ,kg}{weigh\ initial} \times 100 \qquad (7)$$

Quality loss. Rejects such as discolored, 'hubad', 'kambalan', pickles, and oversized which were not acceptable in the wholesale market but sold at a lower price in smaller markets were the basis of quality loss.

Moreover, at the cold storage, every month total weight of rotten and sprouting were recorded as rejects as basis for the quality loss.

$$\%\text{ quality loss} = \frac{wi\text{-}reject}{wi} \times 100 \qquad (8)$$

RESULTS AND DISCUSSION

Postharvest Practices

Harvesting/Piling. Farmers in Nueva Ecija determined the maturity of bulb onion by the number of days after planting (110 days) and when the leaves were bended. Uprooting started at 6 in the morning and simultaneously piling the bulb. Each pile represented one group of laborer that uproot the onion (Figure 1.)

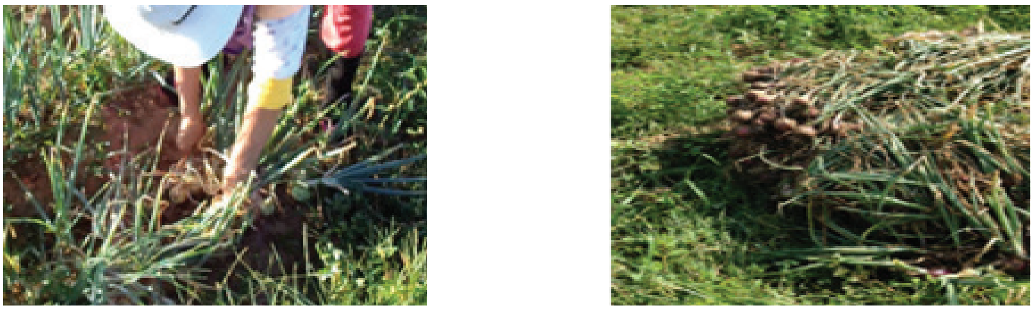


Figure 1. Harvesting of red and yellow bulb onions by uprooting the plant and temporary piling in the farm, Nueva Ecija, 2015

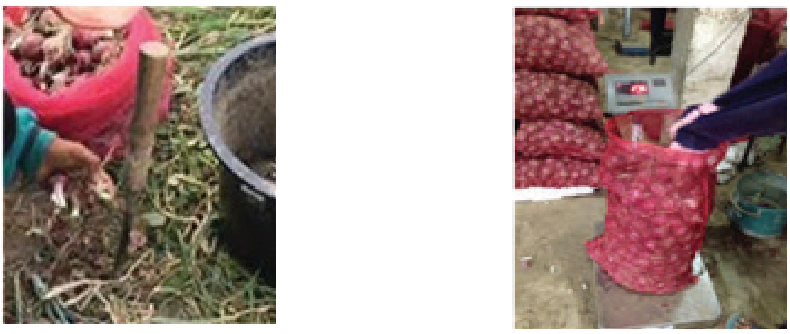


Figure 2. Cutting of leaves and separating marketable and non-marketable rejects, Nueva Ecija, 2015

Figure 3. Loading of bulb onions from the farm to trader's place, Nueva Ecija, 2015

Figure 4. Cleaning/sorting, weighing and packing of bulb onion in the trader's area, Nueva Ecija, 2015

Figure 5. Loading at the traders' area and unloading in Divisoria market, 2015

Marketing. The wholesaler/retailer displayed onions sometimes according to sizes. However, there were buyers preferred to buy in sacks, so segregating according to size was not necessary. The buyers picked up their orders from the stall of the wholesaler/retailer. Bulb onions were sold at Php25/kg retail or at Php420/ bag (Figure 5).

Postharvest losses

In marketing bulb onions, quality was very critical because trader priced them according to appearance and size. So quality loss here was treated separately from the physical loss incurred by the different players involved in the chains.

Physical postharvest losses incurred by the red bulb onion chain totaled to 31.49% while quality loss was recorded at 32.41%. From the physical loss, farmers incurred the 3.28% or 10% of the total losses while traders incurred the 28.21 percent or the 90% of the total loss which was mainly from the cold storage period (Table 3).

Unharvested and cut bulbs were the sources of loss during harvesting showing that laborers were not carefully uprooting the onion plants thus the 1.52% loss. Cutting of leaves and hauling activities were done in the open field. Quality loss which was due to the classification of produce, farmers incurred around 74% of the total quality loss while remaining 26% incurred by the traders. Farmers did initial sorting in the field accounting to around 8.33% classified as immature and 'hubad'. More quality defects at 15.64% were sorted out as discolored, immature, 'hubad', and 'kambalan' during the cutting of leaves (Table 3).

At the trader's level, sources of physical losses were rotten bulbs and weight loss. Quality losses in this level were identified as immature, 'hubad', 'lapis', pickles and oversized bulb onions. These command lower price in the market.

Excluding the storage loss because yellow bulb farmers did not practice cold storage, the highest loss recorded was from transporting the commodity from the trader to the market which was primarily due to weight loss. The distance from the farm was around 150 to 200 km away and travel time was around four to six hours (departure at 3 to 4 pm). An open truck was used for transporting bulb onions.

Considering physical and quality losses, the average postharvest loss for red bulb onions was around 63.90% (including the storage loss for seven months) and 40.01% for yellow bulb onions.

Table 3. Average postharvest losses incurred from red and yellow bulb onions for local market, Ilocos, 2014

Actor Involved/ Postharvest Activity	**Percent Losses**		**Sources of losses**
	Physical	**Qlty**	
FARMER			
Harvesting	1.52 (1.04-2.0)	8.33	Immature, 'hubad' Unharvested, Cut
Cutting of Leaves	0.20	15.64	Discolored, immature, 'hubad', ''kambalan', weight loss
Hauling to nearest road	1.56 (1.50-1.62)		Weight loss
TRADER			
Cleaning/sorting/packing	0.70	8.44	Immature, rotten,'hubad', 'lapis' pickles, oversized
Piling	0.77 (0.17-1.37)		Weight loss
Transport	2.85 (2.4 – 3.3)		Weight loss
Storage*	23.89		Rotten, sprouting, weight loss
TOTAL LOSSES	**31.49**	**32.41**	

*7 months observation

CONCLUSION

Research findings showed that postharvest practices of bulb onions were manually done by the farmers and other stakeholders.

Potential interventions such as the development of small-scale onion harvester, mechanical leaf cutter as well as modification and adoption of foreign technologies for local use to address problems on the timeliness, insufficient labor supply, and quantity and quality loss to possibly reduce postharvest losses should be studied. Curing methods and technologies to extend storage shelf-life must be further studied. Trainings courses on best practices or GAP and on postharvest and mechanization should be extended to the stakeholders.

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ASSESSMENT OF THE POSTHARVEST HANDLING SYSTEMS AND LOSSES OF CASSAVA IN THE PHILIPPINES

Gigi B. Calica[1], Joanne T. Ceynas[2] and Renita SM. Dela Cruz[3]

ABSTRACT

The importance of cassava in the Philippines has been increasing over the past decade. The reasons for this development are multifaceted. Cassava has potential to be a major source of calories for poor families because of its high starch content and ease of management, The Food and Agricultural Organization (FAO) tagged it as "a poor people's food in the 21st century crop". With all these world-wide developments in cassava industry, there is need to establish benchmark on this commodity especially with the entry of this commodity from other countries in the local markets/ as a result of ASEAN integration. The study aimed to establish the different postharvest systems and losses to identify relevant mechanization intervention for the cassava industry in the Philippines. Case studies, observations and FGD were employed to collect data and were analysed using descriptive analysis. In Isabela, wet granulation was being practiced and no chipping was done. Total postharvest incurred in Isabela was 7.47%. Farmers contributed around 61% of the total postharvest losses and traders around 39%. The highest postharvest losses incurred by the chain were harvesting and wet granulation which comprised around 74% of the total losses.

In South Cotabato, chipping and dry granulation were being practiced. Total postharvest losses were recorded at 9.56% wherein farmers incurred the 47% of it while the wholesaler/trader/cooperative contributed the 53% of the chain's losses. Sources of harvesting loss for farmers were unharvested, cut, rotten, uncollected and uncut tubers. Wholesaler/trader/cooperative who employed the chipping and granulation activities incurred the highest loss mainly because of the uncollected fine dust and weight loss. Recommended potential interventions include: modification of foreign mechanical planters, use of mechanical digger and chipper, improvement of existing granulators, establishment of village level drying systems for cassava chips, and conduct of seminars and training courses on good agricultural practices (GAP).

Keywords: Cassava, Granulation, Intervention, Mechanization, Postharvest losses, Postharvest systems, Processing

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INTRODUCTION

Cassava (Manihot esculenta), locally known as "kamoteng kahoy, kawoy" or "balinghoy", is second to sweet potato, in terms of area harvested (hectarage) among the root crops produced in the country. Cassava is grown mostly in Central Visayas, Bicol, Central Mindanao, Eastern and Western Visayas, Western and Southern Mindanao, and Southern Tagalog (DA-AFMIS, 2010).

Cassava is one of the important root crops in the Philippines because of its many uses. Aside from being used as food, and feed ingredients, cassava is also used in the manufacture of industrial products. It is also used as raw material in the production of ethanol. Moreover, cassava can be processed into different food products with higher economic value (Figure 1). The demand for cassava as raw material for industrial uses dramatically increased. However, this demand is not fully satisfied due to low cassava production (DA-Agriculture and Fisheries Information Service, 2013).

Cassava, among others, is also one of the crops mentioned in the Biofuel Act as a possible source of biofuel. Given the prospect of attaining optimal productivity (through fertilization, irrigation, use of improved varieties that can reach up to 20 to 40 tons/ha/yr), ethanol yield from cassava becomes comparably better than those from other feedstock such as sugarcane or sweet sorghum. Improved production efficiency in the future can lead to increased profitability for farmers by tapping the existing and potential local and export markets.

The importance of cassava in the Philippines has been increasing over the past decade. The reason for this development is multifaceted. Cassava has potential to be a major source of calories for poor families because of its high starch content and ease of management. Report by the Rome-based Food and Agriculture Organization (FAO) said cassava has a huge potential and could turn from "a poor people's food into a 21st century crop" if grown according to a new environment - friendly farming model.

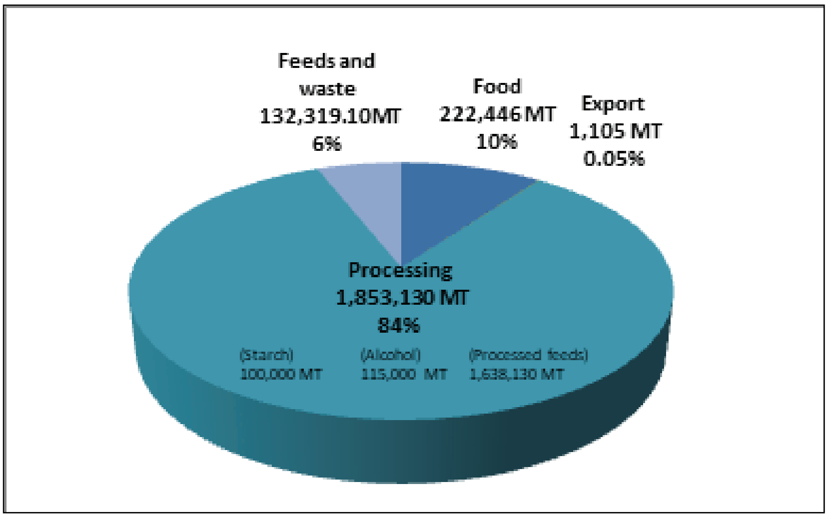
Released on May 28, 2013, the report noted that global cassava output has increased by 60% since 2000, suggesting that the yields could be boosted by up to 400%. (Manila Bulletin's Cassava as a Global Crop, 2013)

The increasing trend in yield and production was a result of the increase in area planted due to cassava's high market potential in the Philippines. The largest area planted to cassava was reported in ARMM is followed by Bicol Region and Eastern Visayas. For the volume of production ARMM still at the top having 51% of total production followed by Northern Mindanao of 17% and 6% in Bicol Region. Northern Mindanao registered the highest yield per hectare followed by SOCCSKARGEN and Cagayan Valley (BAS, 2012). The highest yield was reported in Misamis Oriental followed by Bukidnon and Lanao del Sur. Lanao del Sur has the highest volume of production followed by Basilan and Bukidnon. Largest area planted is in Lanao del Sur followed by Sulu and Tawi-tawi. (BAS, 2012).

In terms of import, cassava products imported by the Philippines are in the form of the following: Manioc (cassava) with high starch or inulin content fresh, chilled, frozen or dried, other than sliced or in form of pellet; flour, meal or powder of manioc; manioc starch; residues of starch manufacture and similar residues of manioc; and residues of starch manufacture and similar residues other than manioc (cassava) or sago, whether or not in the form of pellets (BAS, 2014).

The Philippines' highest imported product from cassava is in the form of manioc (cassava) starch from Thailand, Vietnam, Indonesia, USA, Malaysia, Singapore and South Africa. Thailand contributed the highest volume of 50.11 MT from January to December 2013 (BAS, 2014).

Meanwhile, the country's highest cassava product for export is in the form of manioc (cassava) with high starch or inulin content, fresh, chilled, frozen or dried, other than sliced or in form of pellets. Canada has the highest demand for such cassava product with a volume of 438.31 tons from January to December 2013 (BAS, 2014).



Source: Bureau of Agricultural Statistics, 2011

Figure 1. Cassava utilization in the Philippines, 2011

METHODOLOGY

Conceptual Framework

The project adapted the value chain framework using the Value Chain Diagnostic for Industrial Development by the United Nations Industrial Development Organization (UNIDO) 2010. Under given conditions, this allows understanding on how the industry operate and coordinate to ensure that primary materials are transformed, stored, transported and reach end-consumers in certain form and quality. Value chain diagnostics look at the existing constraints and opportunities to value chain development which are multiple in nature. It also looks at the various effects that operations in the chain have on groups of people (e.g., with regard to poverty reduction, employment, income generation, economic growth, or environmental sustainability).

Study Sites and Data Collection

Study areas were Isabela in Luzon and South Cotabato in Mindanao. South Cotabato was chosen due to peace and order situation in the top producing areas in Mindanao. Key informant interviews with the local government officials, provincial and municipal agriculturists, as well as cooperative or group leaders knowledgeable on cassava production and marketing were tapped to gather the various issues, problems and other necessary information regarding cassava production, handling and marketing.

Farmers, traders, agents and processors were gathered in focus group discussions (FGD) to understand the market chains of selling cassava tubers and granulated cassava in the local market. The major postharvest practices (i.e., farm to the market) identified in the FGDs were adapted for the case studies. Case studies were conducted to document the current postharvest practices of the different stakeholders involved. Alongside with the documentation, measurement of the actual quantitative and qualitative losses incurred at each level of marketing chain and their possible causes were likewise done.

Site visitations of the identified existing facilities and technologies for cassava were also conducted. Information gathered were processed and analyzed qualitatively. Potential interventions were proposed to improve the current industry.

Loss Measurements

The market chains observed for the conduct of loss measurement were the chains from the farmer/grower to the processors of cassava.

The research team worked backwards to identify the various types of intermediaries involved in the product handling and traced back the handling routes and places where commodities passed through and finally the origin or production area where the farmer and local trader-cooperators were identified and selected.

Two sets of cooperators each for Luzon and Mindanao markets were identified. Selection of cooperators was primarily based on the willingness of the different actors of the particular chain to allow the project team to conduct the handling trials while they were doing their respective marketing activities in the chain.

At each step of the route, the operations were observed, quality and losses (nature and extent, whenever possible) of the commodity were documented.

Sampling Procedure and Sampling Size

Postharvest losses were measured quantitatively and qualitatively using the procedure developed by Maranan et al in 1996 and the BPRE and PHTRC in 2009.

Two procedures were adopted because Luzon practiced wet granulation while Mindanao performed dried granulation.

Luzon

1. Ten 2mx2m sampling strings were randomly placed in the area
2. Plants within the sampling area were harvest ed manually. Harvested, unharvested, rotten tubers were collected and placed in a sacks or plastic bags separately.
3. Harvested tubers were chopped into smaller size by using a mechanical granulator. Wet granules were collected and piled in sacks.
4. Fresh granules were dried in the drying pavement and barangay roads for two days.
5. Dried cassava granules were delivered to Villa Luna Multipurpose Cooperative.

Mindanao

1. Ten 2mx2m sampling strings were randomly placed in the area
2. Plants within the sampling area were harvested manually. Harvested, unharvested, rotten tubers were collected and placed in sacks or plastic bags separately.
3. Harvested tubers were manually chopped. Larger tubers were peeled and chipped. Un peeled tubers were mixed with peel from pee ling.
4. Peeled and unpeeled chipped cassava were collected separately and piled in sacks.
5. Both peeled and unpeeled chipped cassavas were dried separately using a corrugated drying pavement.
6. Usually, drying period is two to three days. However, during the conduct of loss measurement, drying period last to nine days due to bad weather condition.
7. Dried cassava chips were chopped into smaller size using a mechanical granulator. Dried granules were collected and piled in sacks.
8. Dried cassava granules were delivered to feeds manufacturer.

Methods of Analysis

Quantitative/Weight Loss. The initial weight at the farm of the total volume marketed and the samples were noted. Final weight of the samples marketed at the wholesale level was also measured. At the farmer level, samples were returned to the lot after the quantitative analysis.

The commodity marketed by the farmer-cooperator was followed through by the team until it reached the first trader level. The same procedure for quantitative/weight loss at each trader level was done for each handling point until the commodity reached the retail level.

The information on the actual loss measurement was used not only to measure losses but also to identify what improved practices and/or technology intervention are needed to improve the system.

Quantitative/weight loss was computed using the following formula:

$$\%\ \text{weight loss} = \frac{wi-wf}{wi} \times 100 \qquad (1)$$

Where:

Wf = final weight of the sample/commodity at each handling point

Wi = initial weight of the sample/commodity at each handling point

Moreover, ten spots of sampling frames measured at 2 m x 2 m were placed at random in the farm site. After measuring the sampling frame, sticks, string or straw were used to mark the boundaries of each frame. Using these frames the following losses were determined:

Harvesting loss. After harvesting, the research team carefully collected the un-harvested produce left in the field whether intentional or not, but which the farmer did not collect. These products were left out, by-passed, shattered or have fallen on the ground by the harvesters. After collection, weighing the commodity was done to estimate the harvesting loss using the prescribed formula.

harvesting loss (HrL) =

$$\frac{Ave.\ wt\ of\ samples}{m2} \times \frac{10{,}000m2}{ha} \quad (2)$$

harvesting loss (%HrL) =

$$\frac{harvesting\ loss,kg}{potential\ yield,kg} \times 100 \quad (3)$$

Hauling Loss. After unloading the cassava tubers from the bamboo cart or hauling truck, all the produce that were left and were not recovered or totally ignored by the farmer were manually collected and weighed.

harvesting loss (HrL) =

$$\frac{Ave.\ wt\ of\ samples}{m2} \times \frac{10{,}000m2}{ha} \quad (4)$$

hauling loss (%HL) =

$$\frac{harvesting\ loss,kg}{potential\ yield,kg} \times 100 \quad (5)$$

Granulation loss. The project team placed underlay around the periphery of the canvas or plastic sheets laid out by the farmer or the granulating crew to catch the commodity that would shatter or scatter during the operation. Products neglected or not collected by the crew were collected and weighed by the project team and were considered part of the granulating loss.

Granulation loss (% GL) = (6)

$$\frac{granulating\ loss,kg}{total\ granulated\ cassava,kg + sum\ of\ granulating\ losses,kg} \times 100$$

Drying loss. For drying loss, weights and moisture content of products were taken before and after drying trials. Portable weighing scales were used in weighing the products. Drying loss was classified as the over-drying loss which was due to extended drying and delayed collection of the grains; and the system loss which included spilled and scattered produce swept and recovered by the team after completion of the drying operation.

Drying loss (% DL) = % LO + % SL

Losses due to over drying (LO):

$$\%LO = \frac{weight\ @13MC-w}{weight\ @13MC} \times 100 \quad (7)$$

Losses due to spillage (SL):

$$\%SL = \frac{weight@13\%MC-actual\ weight}{weight@13\%MC} \times 100 \quad (8)$$

Expected weight loss:

$$wf = wi\ \frac{100-MCi}{100-MCf} \quad (9)$$

Data collected from the key informant interviews of farmers/growers and traders were analysed using descriptive analysis with the aid of SPSS (Statistical Package for Social Sciences) computer software.

RESULTS AND DISCUSSION

Postharvest Practices

Uprooting. Uprooting was done manually. It was the most difficult part of harvesting because it required one to three persons per stalk depending on the soil condition (Figure 2).

Cutting of stalks. Isabela farmers cut the tubers from the stalks after uprooting. The stalks were piled and bundled. They were stored to be used as planting material for the next planting season. Planting material can be bought at Php10 per bundle (1bundle = 100 stalks). On the other hand, Mindanao farmers cut the stalks before uprooting the cassava tubers (Figure 3).

Cutting of Tubers/Piling. Cutting of tubers using bolo was done by around 10 women until lunch time. The tubers were piled in the field and collected in the afternoon using tiklis/bukag (Figure 4).

Hauling/Unloading. After all tubers were collected from the field and loaded to a bamboo cart pulled by a carabao, Isabela farmers delivered them to the granulation/drying area. The distance from the field to the granulation/drying area was around three kilometers. Unloading the cassava tubers from the bamboo cart was done by four laborers (Figure 5). Mindanao farmers used trucks in transporting their harvests to the cooperative.

Chipping/peeling. Chipping was practiced in Mindanao only and it was done manually by cutting the tubers diagonally or crosswise using a bolo or knife (cleaver type). Big tubers were peeled and separated from unpeeled tubers. Peels removed were cut into smaller sizes and mixed with the chipped unpeeled cassava. Chipped, peeled and unpeeled, chipped cassava were collected and separately collected and placed in sack for weighing (Figure 6).

Granulation. In Isabela, fresh tubers were granulated in the drying area using a multicrop thresher, a day after harvesting. There were seven laborers assisting in the granulation process which lasts for four hours. The time of granulation depends on the volume. Spilled granules were swept and collected.

In Mindanao, dried chipped cassava granulation was done separately for the peeled and unpeeled because the former commands higher price than the latter. Dried chips were collected using bukag and loaded to a mechanical granulator. The peeled and unpeeled cassava granules were collected separately using polypropylene sack. Dried cassava granules were piled and stored in a warehouse until the scheduled delivery period to the feeds manufacturer (Figure 7).

Drying. Multi-purpose drying pavement and barangay roads were the common drying facility in Isabela. Cassava granules were spread out on the pavement with three inches thick for two to three days depending on the weather condition. Flaky granules when cracked were an indicator that they were already dried.

On the other hand, drying cassava chips was done on corrugated pavements in Mindanao. Chipped peeled and unpeeled cassava were spread out separately on the pavement. A standby tarpaulin to cover the chipped cassava during the night was used to protect them from possible rains. On sunny conditions, drying took two to three days. However, during the study, sundrying took almost two weeks due to bad weather condition (Figure 8).

Sacking/Loading. Dried granules were collected using broom and scooper. Sacking of dried cassava granules was done every day and filled sacks were piled at the sides of the pavement. Tarpaulins were used to cover the granules to protect them from rain, chickens and birds. The packed dried granules were loaded to a delivery truck a day before transport to the trader (Figure 9).

Transport. Early in the morning, the dried cassava granules were transported to a cooperative in Cauayan, Isabela, about 21 kms away from Sta. Victoria, Naguilian, Isabela. Travel time of delivery was about an hour from the farm area (Figure 10).

Delivery. Upon arrival, the truckload was weighed through a truck-scale. A receipt was given to the client/customer indicating the net weight of the delivery. Payment was claimed at the cashier's office (Figure 11). At the feed manufacturing plant, random sampling was performed for quality analysis. Results would be the basis for the quality and price of the delivery.

Figure 2. Uprooting the cassava plant, Isabela and Mindanao, 2014

Figure 3. Cutting of stalks, Isabela and Mindanao, 2014

Figure 4. Cutting of tubers and piling them for collection, Isabela and Mindanao, 2014

Figure 5. Hauling and unloading using carabao and sled or truck, Isabela and Mindanao, 2014

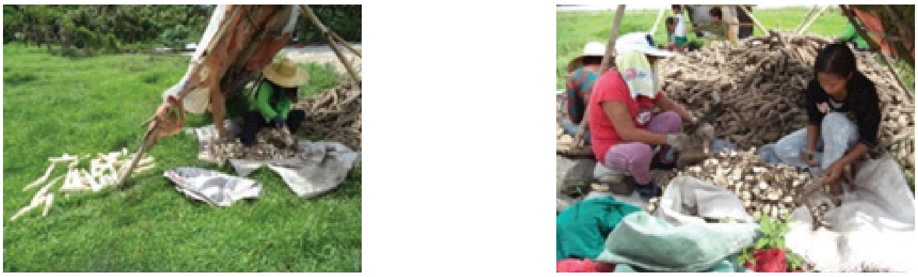


Figure 6. Manual peeling and chipping of cassava tubers, Mindanao, 2014

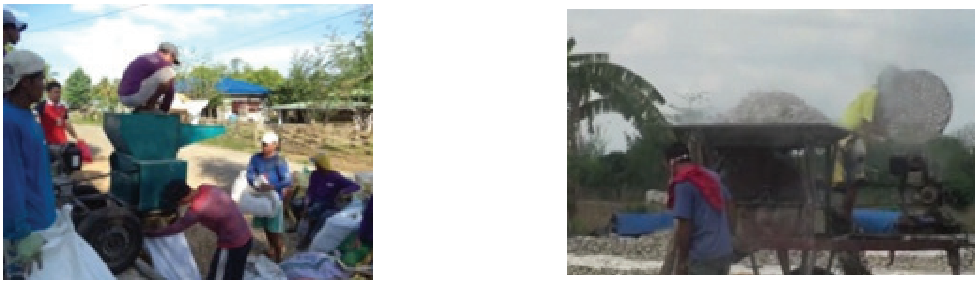


Figure 7. Wet and dry granulation of cassava tubers, Isabela and Mindanao, 2014

Postharvest losses

Based on the case studies conducted in Isabela and Mindanao, postharvest losses incurred in the cassava industry was attributed to handling and weight loss because of the distance and time element in transporting the commodity from one point to the other until it reached the end user.

In Isabela, wet granulation was being practiced and no chipping was done. Farmers were only involved in the harvesting and hauling of crop which contributed around 61% of the total postharvest losses. On the other hand, the traders took care of the rest of the activities up to marketing experiencing the remaining 39% of the losses.

The highest postharvest losses incurred by the chain were harvesting and wet granulation comprising around 74% of the total losses (Table 1).

In South Cotabato, total postharvest losses was recorded at 9.56% with farmers incurring the 47% of this and the wholesaler/trader/cooperative contributing 53% of the chain's losses. Sources of harvesting loss for farmers were unharvested, cut, rotten, uncollected and uncut (Figure 12).



Figure 8. Drying of granulated cassava using barangay roads and cassava chips (peeled and unpeeled) in corrugated pavements, Isabela and Mindanao, 2014


Figure 9. Collecting dried cassava granules and packed in sacks ready for loading to the delivery truck, Isabela and Mindanao, 2014

Figure 10. Delivery of dried cassava granules to the cooperative assembler, 2014

Figure 11. Weighing truckload of dried cassava granules on a truck scale, 2014

Wholesaler/trader/cooperative who employed the chipping and granulation activities incurred the highest loss mainly because of the uncollected fine dust and weight loss (Table 2). On the average, postharvest losses incurred by the entire cassava chain was at 9.86%. Of the total loss around 46% contributed by the farmers while 54% by the wholesaler/ trader/ cooperative (Table 3).

Problems Encountered and Available Technologies

Aside from the problem of insufficiency of cassava supply, the industry also encountered difficulty in uprooting the cassava tubers, chipping, drying and the non-uniformity of granule size resulting to around 30% converted into dust.

Available technologies were Brazilian mechanical cassava planter, Thai cassava mechanical digger, manual and mechanical chippers, PHil-Mech mechanical belt dryer, multi-crop threshers used as granulator and fabricated granulator. Also, imported machines such as planters, diggers, and chippers are available in the market.

Table 1. Postharvest losses for cassava products from Isabela, 2014

Actor	Activities	Postharvest losses, %	Sources of Losses
Farmer	Harvesting	2.74	Unharvested, cut, rotten, uncollected, uncut
	Hauling	1.81	Weight loss
Wholesaler/ Trader/	Granulation	2.73	Weight loss, fine dust
Coop	Drying	Nil	
	Marketing	0.19	Weight loss
	TOTAL	**7.47**	

Table 2. Postharvest losses for cassava products from South Cotabato, 2014

Actor	Activities	Post harvest losses, %		Ave. losses, %	Sources of Losses
		Unpeeled	Peeled		
Farmer	Harvesting	2.79	2.79	2.79	Unharvested, cut, rotten, uncollected, uncut tubers
	Hauling	1.70	1.70	1.70	Weight loss
Wholesaler/ Trader/ Coop	Chip-ping	3.58	1.76	2.67	Weight of peels, weight loss
	Granulation	3.02	1.79	2.40	Weight loss
	Drying	Nil	Nil	-	
	Mrktg	Nil	Nil	-	
TOTAL		**11.09**	**8.04**	**9.56**	

Table 3. Average postharvest losses for cassava products from Isabela and Mindanao, 2014

Actor	Activities	Post harvest losses, %	Sources of Losses
Farmer	Harvesting	2.76	Unharvested, cut, rotten, uncollected, uncut tubers
	Hauling	1.76	Weight loss
Wholesaler/ Trader/	Chipping*	2.67	Weight of peels, weight loss
Coop	Granulation	2.57	Weight loss, fine dust
	Drying	Nil	
	Mrkting	0.10	Weight loss
	TOTAL	**9.86**	

Figure 12. Unharvested, cut, rotten, uncut, and uncollected cassava tubers as sources of postharvest losses for cassava, Isabela and Mindanao, 2014

CONCLUSION

Total postharvest losses incurred by Isabela and South Cotabato cassava chains were recorded at 7.47% and 9.56% on the average, respectively. Total postharvest losses of Philippine cassava was at 9.86%.

To ensure the quality of dried granules, modification and evaluation of the existing mechanical granulators is recommended to lessen the volume rejected due to non- conformance to the recommended granule size.

To reduce postharvest losses, it is recommended that researchers and engineers should look at the possibility and the prospect of designing and developing cassava granulator producing cassava granules in compliance with the Philippine National Standards (PNS).

Further, modification, fabrication and evaluation of the existing cassava planter, cassava chipper and cassava peeler from other countries for easier and faster processing of dried cassava granules are recommended for further studies and for possible reduction in losses. Improvement of existing granulators and establishment of village-level cassava drying systems are also proposed.

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ASSESSMENT OF THE POSTHARVEST HANDLING SYSTEMS AND LOSSES OF CARDAVA BANANA IN THE PHILIPPINES

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ABSTRACT

The Philippine Cardava banana has recently captivated the international market because of its nutritional value and versatile of use. The growth potential for Cardava processed products remains high. With more effort to disseminate relevant information and improving the industry, more people can be enticed to go into business of Cardava production and processing. To give the government relevant data in crafting policies for upgrading and promoting the Cardava banana postharvest industry, this study was conducted. The study aimed to assess the different postharvest systems and losses of Cardava banana to identify relevant mechanization interventions industry. Case studies and Focus Group Discussion (FGD) were employed to collect data and were analysed using descriptive analysis.

The postproduction systems for Cardava banana included harvesting, on-farm hauling, dehanding, off-farm hauling, loading, piling and unloading, and marketing. Production of Cardava banana in remote areas of Luzon, the local market chain resulted to extensive consolidation and transportation of the commodity before it reaches the market. Meanwhile, Mindanao which supplied the international market immediately after harvest within the day. Harvesting in all areas was done manually.

Postharvest losses incurred by the local market chains reached around 15.45% due to dehanding, immature hands and weight loss while export market chains recorded around 15.58%. Sources of losses were the marketable rejects, deformities and weight loss.

Potential interventions to reduce postharvest losses are the use of the simple scoop for dehanding, tramline for hauling and transport and ethylene scrubber to delay ripening. Recommended for further research work are the development of peeling machine and modification of the existing banana chipping machine.

Keywords: Cardava banana, Export, intervention, Postharvest losses, Postharvest systems Processing

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INTRODUCTION

Cardava, also known as 'saba' banana in the Philippines has been traditionally grown for local market. In fact, according to a report of the Bureau of Agricultural Research in 2009, Cardava is the world's fourth most important staple next to rice, corn, and wheat.

The Philippine Cardava banana has recently captivated the international market because of its nutritional value and versatile use. Cardava is the specific variety of banana in processing banana chips. In Mindanao alone, there are 26 processing plants for banana chips with a capacity of 20 to 60 tons per day per plant.

The strength of the banana industry lies on its big hectarage, which is a little more than half (53.8%) of the total land area planted to fruits (621,861 has). The country is also blessed with favorable climate, well suited for growing bananas all year round. There are already existing banana cultivars accepted in domestic and export markets. The major cultivars are Cavendish and Señorita for the fresh export market, Cardava for processed products (chips and crackers), Lakatan, Bungolan, Latundan, and Señorita for fresh local market.

The average banana production in the country from 2012 to 2016 was estimated at 8,029,419 mt wherein 56.24% is Cavendish, 11.70% is lakatan and 32.06 % is Cardava banana (Figure 1).

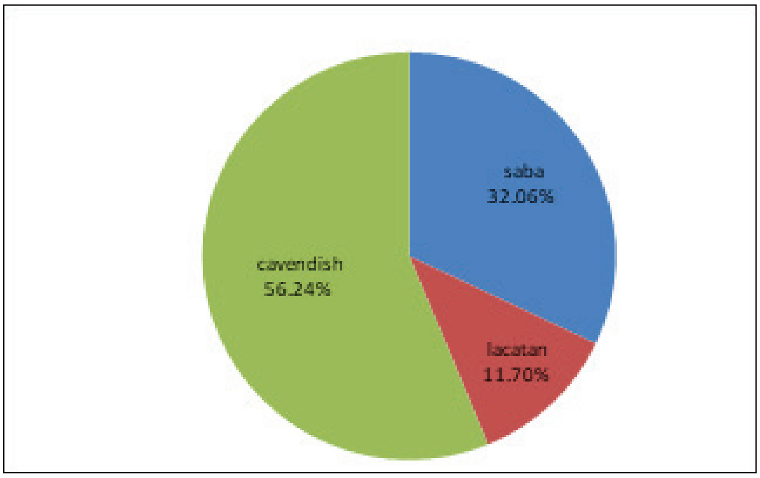
The production of bananas is however highly concentrated in Asia. The outputs of India, China and the Philippines account for about 45% of the total value. Other leading regions were the Americas with 26.6% followed by Africa with 15.6% (TheGlobalEconomy.com, FAO, 2014)

The growth potential for banana processed products remains high. The country has still a large area of land suited for banana production while its population growth rate remains above 2% annually. With more efforts to disseminate relevant information, more people can be enticed to go into the business of banana production and processing (Arturo et al. 2004).

In the Philippines, banana stands out as the most important fruit crop constituting a significant portion in the country's export revenue. Among the many banana cultivars grown throughout the country, 'saba' or Cardava banana (Musa balbisiana) is considered as one of the leaders in terms of production and trade. It is one of the important sources of food in the rural areas which is often used as extender, supplement or substitute staple food such as rice and corn.

Almost every part of Cardava can be economically utilized. It is eaten fresh as dessert or when cooked and processed into the popular banana chips. The inflorescence is consumed as vegetable while the leaves are used as wrapping and decorative materials. The pseudostem is chopped finely, cooked and used as feed for hogs, cattle, and poultry.

The study aimed to assess the different postharvest systems and identify relevant mechanization interventions for the Cardava industry in the Philippines. Cardava banana growers/farmers usually market unripe and semi-ripe bananas (Banana AgriChain Competitiveness Enhancement, 2007). Unripe banana is preferred by the processors, 30% goes to contractors and barangay agents while micro-processors get 5% share. The remaining 65% which comprises the Cardava banana processors and exporters' rejects (semi-ripe and ripe bananas) go to the assemblers and distributors which supply the wet market (Figure 2).



Source: Philippine Statistics Authority
Figure 1. The average percent distribution of banana in the Philippines according to variety, 2012-2016

METHODOLOGY

Conceptual Framework

The project adapted the value chain framework using the Value Chain Diagnostic for Industrial Development by the United Nations Industrial Development Organization (UNIDO) 2010. Under given conditions, it permits you to understand how the industry operate and coordinate to ensure that primary materials are transformed, stored, transported and reach end-consumers in certain form and quality. Value chain diagnostics looks at the existing constraints and opportunities to value chain development, which are multiple in nature. It also looks at the various effects that operations in the chain have on groups of people, e.g., with regard to poverty reduction, employment, income generation, economic growth, or environmental sustainability.

Study Sites and Data Collection

Study areas were Isabela in Luzon and Davao Region in Mindanao, the identified top Cardava banana producing provinces in the Philippines.

Key informant interviews such as the local government officials, provincial and municipal agriculturists, as well as cooperative or group leaders knowledgeable on Cardava banana production and marketing were tapped to gather the issues, problems and other necessary information regarding Cardava banana production, handling and marketing.

Farmers, traders, agents and processors were gathered in focus group discussions to understand the market chains of selling fresh and processed Cardava in the local and export markets. The major postharvest practices (i.e., farm to the market) identified in the FGDs were adapted for the case studies.

Case studies were conducted to document the current postharvest practices of the different stakeholders involved. Alongside with the documentation, measurement of the actual quantitative and qualitative losses incurred at each level of marketing chain and their possible causes were likewise done.

Site visitations of the identified existing facilities and technologies for Cardava were also conducted.

Loss Measurements

The market chains observed for the conduct of loss measurement were the chains from the farmer/grower to the processors of Cardava banana or 'saba'.

The research team worked backwards to identify the various types of intermediaries involved in the product handling and traced back the handling routes and places where commodities passed through and finally the origin or production area where the farmer and local trader-cooperators were identified and selected.

Two sets of cooperators each of the major chains of Luzon and Mindanao markets were identified. Selection of cooperators was primarily based on the willingness of the different actors of the particular chain to allow the project team to conduct the handling trials while they were doing their respective marketing activities in the chain.

At each step of the route, the operations were observed, quality and losses (nature and extent, whenever possible) of the commodity were documented.

Sampling Procedure and Sampling Size

At the farmer level, 1 farmer was selected as cooperator. About 2 to 10% on the total volume harvested by the farmer-cooperator was taken as samples for the study. The samples were randomly selected and taken from the farm. The initial weight at the farm of the total volume marketed was noted. Then the final weight of the samples marketed at the agent/consolidator level was also measured until it reached its final destination.

Postharvest losses were measured quantitatively and qualitatively using the procedure developed by Maranan et al. in 1996 and the BPRE and PHTRC in 2009.

Methods of Analysis

Quantitative/Weight Loss. The initial weight at the farm of the total volume marketed and the samples were noted. Final weight of the samples marketed at the wholesale level was also measured. At the farmer level, samples were returned to the lot after the quantitative analysis.

The commodity marketed by the farmer-cooperator was followed through by the team until it reached the first trader level. The same procedure for quantitative/weight loss at each trader level was done for each handling point until the commodity reached the retail level.

Quantitative/weight loss was computed using the following formula:

$$\%\ \text{weight loss} = \frac{wi-wf}{wi} \times 100 \qquad (1)$$

Where:

Wf = final weight of sample/commodity at each handling point

Wi = initial weight of the sample/commodity at each handling point

Harvesting loss. After harvesting, the research team carefully collected the un-harvested produced left in the field whether intentional or not, but which the farmer did not collect. These products were left out, by-passed, shattered or have fallen on the ground by the harvesters. After collection, weighing the commodity was done to estimate the harvesting loss using the prescribed formula.

harvesting loss (HL) =

$$\frac{\textit{Ave. wt of samples}}{m2} \times \frac{10{,}000m2}{ha} \qquad (2)$$

harvesting loss (%HL) =

$$\frac{\textit{harvesting loss,kg}}{\textit{potential yield,kg}} x100 \qquad (3)$$

Dehanding loss. The research team collected the usual two bottom hands of the bunch and other hands or fingers that farmers presumed that the consolidator would not accept.

Dehanding loss (%DL) =

$$\frac{\textit{total weight dehanding loss,kg}}{\textit{total weight initial,kg}} \times 100 \quad (4)$$

RESULTS AND DISCUSSION

Postharvest Practices

For the Local Market

The discussion below describes the postharvest practices of the different chain actors of Luzon catering the local markets for Cardava banana.

Harvesting/Hauling. Farmers in Isabela, Luzon determined the maturity of Cardava banana by the number of months after planting (15 to 18 months), the roundness or fullness of fingers and the number of leaves (2 to 3 leaves) left on the plant. Harvesting started at seven in the morning to four in the afternoon. Usually two persons harvest the Cardava banana. One cut the tree and the bunch using bolo while the other handled and hauled the bunch to several designated assembly areas within the farm.

A carabao sled hauled them to the roadside assembly area (Figure 2.)

Dehanding. When all harvested bunches had been assembled in a given area, the farmer performed dehanding using bolo. The farmer removed the last two hands of the bunch and other hands with defects not acceptable to the consolidator. Afterwards, the bananas were loaded to carabao drawn sled and delivered to the consolidator's assembly area (Figure 3).

Figure 2. Cutting of banana stalks and bunch, hauling manually or using carabao drawn sled, Isabela in Luzon, 2014

Figure 3. Dehanding using a bolo and piled Cardava hands, Isabela in Luzon, 2014

Figure 4. Weighing, counting/sorting of Cardava bananas at the consolidation area and bulk piling inside the delivery truck, Isabela in Luzon, 2014

Figure 5. Truck used for transporting Cardava banana from Isabela to Urdaneta market, Pangasinan in Luzon, 2014

Hauling. Farmers hauled Cardava bananas to the consolidator's area by means of carabao-drawn sled. They unloaded the commodity in separate piles for easy identification when the consolidator started to count and sort.

Consolidation. Wholesaler/trader accepted and bought Cardava banana from the farmers. Consolidation actually took two days to accumulate a truckload stocks for delivery to Urdaneta, Pangasinan market.

Counting/Sorting/Weighing/Loading. There were two ways of buying Cardava banana in Luzon, the counting method and the metric system or weight method. After the counting or weighing, the consolidator gives the farmer the computation of the total number of hands as per classification and its total proceeds (Figure 4).

Loading started at 7 in the morning up to 12 noon with two laborers doing the bulk piling of cardava inside the truck while three laborers were hauling them up the truck using 'bukag' or crate.

Transportation. At three in the afternoon, Cardava banana were transported from the farm areas of Isabela to Urdaneta City market in Pangasinan this took about 12 hours. To avoid early ripening, the consolidator put some banana bracts lining in the truck sidings and a tarpaulin roof.

The delivery truck arrived at the Urdaneta wet market at around three in the morning of the following day (Figure 5).

Unloading/Counting/Weighing/Sorting. Unloading of bananas from the truck started at six in the morning when buyers began to inspect the quality of bananas and placed their orders to the wholesaler/trader.

When the wholesaler/trader in Urdaneta market had enough orders unloading/counting/sorting started based on the requirement of the buyers. The method of counting was the same as the consolidator's, (i.e, by 5's applying the classification of good or big, RR or medium and R or small.) This was done together with the consolidator/trader to facilitate the unloading/

counting/sorting and at the same time monitoring the total volume of load based on the wholesaler/trader's counting (Figure 6). In Balintawak, however, metric system was employed.

Marketing. The buyers picked up their orders from the stall of the wholesaler/trader. Sometimes they requested to dip their orders in ethrel solution and packed them in plastic bags at 15 to 17 kg/bag. Wet market retailers preferred ripe and detached cardava fingers.

Transportation. The processor picked up banana orders at seven in the morning. Using a tricycle, he transported the volume requirement to his place (Figure 7).

Processing. Upon arrival in the processing area, two laborers unloaded the bananas and prepared the area for peeling. One of the laborers started to peel using an improvised fork handle while the other chipped the peeled banana with a slicer designed by the processor himself.

After accumulating a pan full of chipped Cardava, the fryer pre-heated the pan with oil for cooking the chipped cardava. Before frying the banana chips small quantity of cooking oil was mixed to prevent the chips from sticking with each other. Frying took five minutes with constant mixing and then removed from heat for cooling (Figure 8). Around 9.70 kg of fresh Cardava bananas were needed to produce one kg of banana chips.

Packing. After cooling the banana chips, packing followed in another room. Four persons performed the packing with its label inserted inside the plastic of 80 g and 230 g packs and sealed using an electric sealer. They usually finished at the wee hours of the morning (Figure 9).

Distribution. Early in the morning the processor distributed the packs of banana chips in the market outside the church. Some had to be delivered to the markets of the neighboring towns.

Consumption. Customers of the processor were the owners of the stalls in front of the Manaoag Church and the stores in the neighboring towns who retailed the banana chips.

For the Export Market

This described the postharvest practices of the different actors in Mindanao who were involved in the export
chains which supplied products demanded by the international market.

Harvesting/Hauling. Farmers in Mindanao determined the maturity of Cardava banana by the number of months after planting (15 to 18 months), the roundness or fullness of fingers and the number of leaves (2 to 3 leaves) left on the plant. Harvesting started at seven in the morning up to four in the afternoon.

Figure 6. Unloading/counting/sorting of Cardava banana by the wholesaler/trader, Pangasinan and Manila market in Luzon, 2014

Figure 7. Small scale processor used tricycle in transporting bananas from the market to his place, Pangasinan in Luzon, 2014

Figure 8. In clockwise: Peeling washing, chipping, 1stfrying, syrupping and 2nd frying, Pangasinan in Luzon, 2014

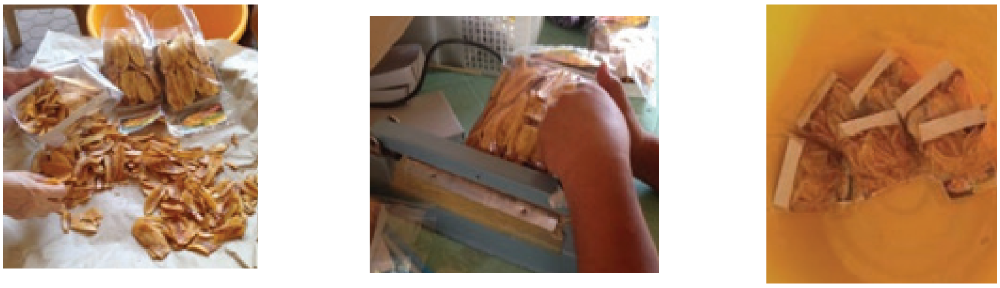


Figure 9. Packing, sealing and banana chips packed in plastic, Pangasinan in Luzon, 2014

Usually two persons harvested Cardava bananas; one cut the stalks and the bunch using scythe while the other handled and hauled two bunches manually using a bamboo pole to the designated area near the roadside (Figure 10).

Dehanding/Weighing/Hauling/Loading When all harvested bunches had been assembled in the roadside, the wholesaler/exporter performed dehanding using a scoop with handle. Using a 'bukag', a classifier weighed the cardava hands and loaded them inside a closed truck van for transporting (Figure 11).

Unloading/Piling. A laborer removed bananas from the 'bukag' and loaded them inside a closed truck van. The bananas were piled in bulk to maximize the space of the transport vehicle. In case of microwavable saba, defingered bananas were transported in crates (Figure 12).

Transportation. The truckload of cardava was transported straight to the processing plant (Figure 13).

Cleaning/Washing. Fresh bananas for export required cleaning and washing. Upon arrival at the packing area, bananas were unloaded to the two water tanks where the laborers cleaned and washed them to remove the latex and dirt (Figure 14).

Weighing/Packing. Around five to six hands of bananas equivalent to 14 kg were weighed and placed on trays. While being conveyed to the packaging area, brand labels and other information about the exporter were stuck on the plastic bag. Cleaned bananas were packed with foam sheets placed in between the hands. The plastic bag was loosely tied and air was vacuumed out and sealed in a box (Figure 15).

Figure 10. Assembly area along the roadside, scythe with handle as harvesting tool and manual hauling using a bamboo pole with cloth tied at the center serving as caution, Mindanao, 2014

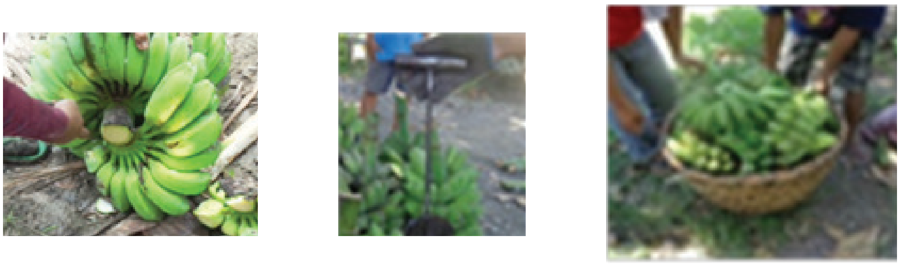


Figure 11. Dehanding using a scythe and a scoop with handle and weighing banana hands or fingers in a'bukag' or crates, Mindanao, 2014

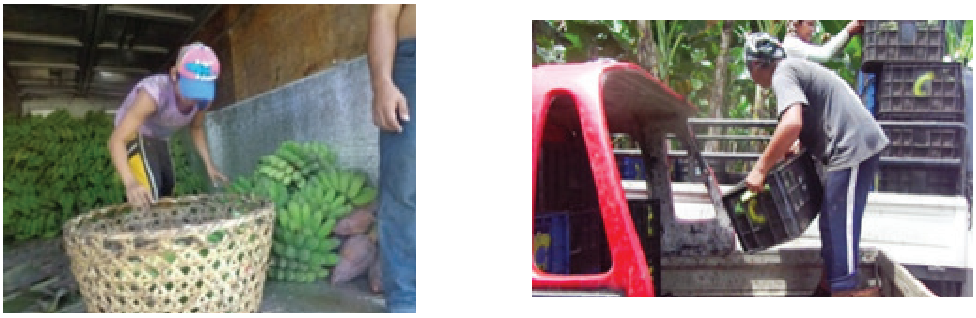


Figure 12. Unloading of cardava from the 'bukag' and bulk piling inside the truck van and piling defingered bananas in crates in a truck, Mindanao, 2014

Figure 13. Closed and open truck transporting cardava banana from the farm to the processing area, Mindanao, 2014

Unloading and processing. Upon arrival at the plant, Cardava bananas for processing were weighed as the payment basis for the suppliers. Processing followed to produce microwavable saba or banana chips for export (Figure 16).

Shipping/Freight. Shipping of fresh and semi-processed Cardava bananas to Japan was once a week as well as the air freight delivery to Dubai. The shipment took one week to reach Japan while the air cargo to Dubai took only more than nine hours.

Consumption. This product catered to the needs of the Overseas Filipino Workers (OFWs) in Japan and Dubai. OFWs used it as one of the ingredients in their cooking and preparation of dessert such as banana cue, fried banana, etc. According to the exporter, the supermarket importer mentioned that even foreigners who tasted the product through their Filipino friends and relatives had started buying the product.

Postharvest losses

Table 1 presents the postharvest losses incurred by the local markets of Cardava banana. Local market chains incurred postharvest losses at around 15.45%.

Harvesting losses at 0.51% was due to the harvesting techniques employed wherein the bunch fell on the ground resulting to bruising and cuts, dehanding using scythe which caused cuts to the banana fingers was recorded at 5.84 %. Moreover, because of the time element (2-3 days) involving the consolidation, unloading, sorting and counting losses incurred by both the consolidator and the wholesaler at 2.75% and 3.92%, respectively were due to weight loss. The use of open truck and bulk piling practices during transport wherein the commodity was exposed to heat incurred weight loss at 0.77% (consolidator) and 1.66% (wholesaler/trader/processor) as well.

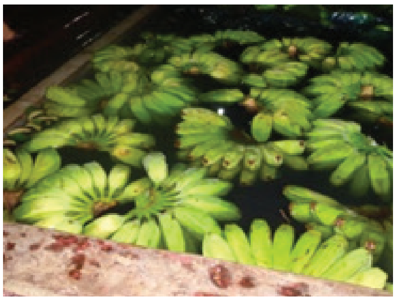


Figure 14. Two water tanks used for cleaning and washing fresh Cardava banana for export, Mindanao, 2014

Figure 15. Clockwise: weighing after washing; conveying the tray to the packaging area; packing Cardava hands in a box with foam sheets in between the hands; and vacuumed and sealed the box, Mindanao, 2014




Figure 16. Different activities in processing Cardava banana, Mindanao, 2014.

Table 1. Postharvest losses of local products of Cardava banana from Isabela and Mindanao, 2014 (Values in Percentage)

Actor	Postharvest Activities	Farm to local Mktg	Sources of Losses
Farmer	Harvesting	0.51 (0-0.51)	Detached due to handling
	Dehanding	5.84 (2.98 – 8.71)	Immature and cuts
Consolidator	Unloading, sorting, counting	2.75	Weight loss
	Loading, piling, transport	0.77	Weight loss
Wholesaler/ Trader/	Sorting, counting	3.92	Weight loss
Processor	Loading, piling	0.94	Weight loss
	Transport	0.72	Weight loss

Note: Figures in parenthesis are ranges

Table 2. Postharvest losses of export products of Cardava banana from Isabela and Mindanao, 2014 (Values in Percentage)

Actor	Postharvest Activities	Farm to export Mktg	Sources of Losses
Farmer	Harvesting	0	-
	Dehanding	13.11 (2.10 – 24.24)	Immature, marketable rejects due to size or cuts deformed
Consolidator	Unloading, sorting, counting	-	Weight loss
	Loading, piling, transport	-	Weight loss
Wholesaler/ Trader/	Sorting, counting	-	Weight loss
Processor	Loading, piling	2.47 (0.54-5.34)	Weight loss
	Transport	-	Weight loss

Note: Figures in parenthesis are ranges

On the other hand, Cardava bananas following the export product chains recorded around 15.58% of postharvest losses due to its standard requirements to meet (Table 2). As documented and observed, exporters did not allow the banana bunch to touch or fall on the ground to avoid bruising and cuts to the Cardava fingers. More so, dehanding practices encountered around 13.11% because of immature hands, cuts, smaller in size and deformities. Cuts were prevented due to the tools that were used such as the scythe or scoop. Deformities in Cardava fingers were rejects in the export market but still marketable for the local market.

The last two bottom hands were immature and smaller and generally considered rejects in the local market hence, were left behind at the farmer level for animal feeds. In export market, they were considered marketable rejects because they did not meet the required size and form by the microwavable banana processor but still acceptable for banana chips processing or for the local fresh market. Some of the losses were due to weight loss because of the distance and time travelled by the commodity and the form of raw materials (hands or in fingers).

Problems Encountered and Available Technologies

Farmers' problems were on the availability of traders during harvest resulting to ripening of Cardava. At the farm level ripe bananas were considered rejects. Farmers had left no choice but to deal with the available traders in the area even if they offered low price for their produce.

Consolidators/traders and processors complained on the low quality of farmer's supply, non-compliance of farmers to the size, weight and appearance standards of the international market Processors catering the export markets expressed that the farmers did not comply with the size, weight and appearance standards of the international market. Supply was ultimate problem for them especially if they had volume requirement to fulfil in the international market. In the field, piled up banana stalks should be utilized for other purposes other than for fertilizer.

Available technologies were fabricated scoop for dehanding, tramline for hauling and transport especially for high elevated areas, ethylene scrubber for retarding the ripening of banana, peeling and chipping machines used for other crops which could be used for banana.

CONCLUSION

In the local market, remote areas were the sources of Cardava banana production resulting to the extensive consolidation and transportation of the commodity before market. In the export market, the produce was marketed immediately within the day. Harvesting in all areas was done manually but in Luzon which catered the local market cut the trunk at the bottom near the ground and let the bunch fall down causing bruising and cuts to the hands. This was avoided by farmers in Mindanao who supplied the export market by cutting the trunk approximately halfway from the ground to prevent the fruits from directly falling down and impacting its weight on the ground.

Loss assessment conducted on fresh Cardava banana showed postharvest losses at 15.45% and 15.58% for the local and export markets. Sources of losses were due to physical loss measured at the farmer level especially on dehanding and weight reduction during handling at trader level. Road condition and lack of transportation facilities in delivering Cardava banana on distant major market outlets like Pangasinan and Balintawak could be attributed to the longer transport time under ambient conditions characterized by high temperature and constant wind exposure.

Recommended potential interventions are the use of the simple scoop for dehanding, tramline for hauling and transport especially to difficult-to-reach areas, use of the ethylene scrubber to delay ripening, development of peeling machine and modification of the existing banana chipping machine.

Moreover, it is recommended to establish a village level banana chips processing, develop a system for semi-processed banana chips for possible delivery to the big companies, and to further process banana stalks left behind in the farm into food, feeds or fiber.

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ASSESSMENT OF THE POSTHARVEST SYSTEMS AND LOSSES OF SHALLOTS IN ILOCOS, PHILIPPINES

Gigi B. Calica[1] and Maggie Mae N. Dulay[2]

ABSTRACT

To face the challenges of ASEAN integration, the Philippine government needs more information on the fruit and vegetable industries so as to craft projects that will address these problems. This paper provided baseline data on shallots particularly on its postharvest practices and mechanization.

Results showed that most of the postharvest practices of shallot (from harvesting to marketing) were done manually. More so, activities were tedious and laborious as well as time consuming. Postharvest losses recorded were at 20.48% for shallot bundled marketed locally, 28.73% for shallot bundled for export market and 30.26% trimmed shallot for export. Problems encountered by the different stakeholders were on lack of labor supply, postharvest facilities, information on best practices and market information.

Potential technology interventions identified include small-scale onion harvester, mechanical leaf cutter and modification of foreign technologies for local shallot industry use. Conduct of studies on the curing methods and insect and disease to extend shelf-life of shallot in storage was recommended. Market research on other potential markets for shallots and development of niche market that is stable were encouraged. Training courses on best practices for shallot production were also suggested.

Keywords: Intervention, Mechanization, Postharvest Losses, Postharvest Practices, Shallot, Stakeholders

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INTRODUCTION

Fruits and vegetables as well as their processed products have been mainstreamed into the human dietary choices in the recent days, primarily because of several studies showing various health benefits associated with the consumption of these products.

With the population increase, sustainable agriculture has to achieve food security in combination with economic viability, social responsibility and have as little effect on biodiversity and natural ecosystems as possible.

However, before achieving all of these, information about the particular commodity from production up to marketing should be studied to come up with the necessary interventions.

Benchmarking is about partnerships, discussion and exchange of information and ideas looking for innovative ways of improving performance and management. It is based on identifying best practices. A particular industry has the opportunity to look at the practices and processes of the other institution for their gain (Harris, 2001).

Kulmala (1999) suggested that benchmarking is basically a process of evaluating and applying best practices that provide possibilities to improve quality. This study focused on the shallot industry of the Philippines.

Shallot supply of Ilocos Norte is high during the months of November to April. On the other hand, Ilocos Sur has two seasons of producing shallots. Its supply starts to peak up in November until January and decreased in February and March. The second crop is very short which is in April only. Majority of the shallots harvested during this time are mostly for sowing purposes for the next cropping season. However, some farmers plant more than they need. The excess is sold in the local market or the exporters. In Nueva Ecija, peak season for shallots is in the months of February to April (Table 1).

Table 1. Harvesting calendar of shallots, Ilocos, Philippines

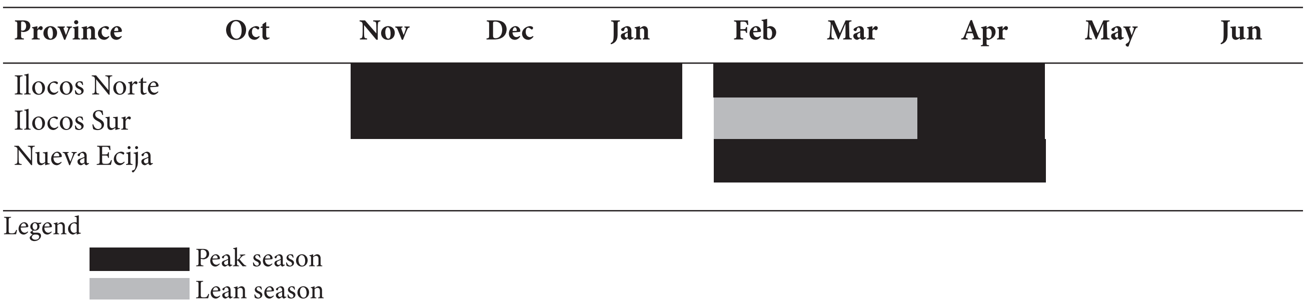

Table 2. Production of shallot onion in the Southeast Asian countries [a/]

Item	Area harvested (ha)	Production (MT)	Yield (MT)	Distribution (%)
Brunei Darussalam [a/]	11	88	8.34	0.01
Indonesia [b/]	104,319	991,390	9.50	80.36
Philippines [c/]	4,183	46,763	11.82	3.79
Thailand [a/]	16,145	195,404	12.10	15.84
Total	**16,156**	**195,493**	**20**	**100**

[a/] Source of basic data: FAO (2009-2012 yields) for Brunei Darussalam and Thailand
[b/] Source: NAFC (2009-2012 yields)
[c/] BAS and OPAG of Nueva Ecija, Nueva Vizcaya, Pangasinan, Ilocos Sur, Ilocos Norte and Occidental Mindoro (2009-2013)

Shallot is mainly produced in Indonesia with 80% of the total production in Southeast Asia. In an interview with an exporter/importer of shallot onion in the Philippines, the country's exports of shallot in Indonesia mainly served as planting material. The Philippine Council for Agriculture and Fisheries (PCAF), then NAFC (2014) cited that Indonesia can grow shallots up to four times a year because they have rain-resistant shallot variety (Table 2). Shallots stored well at temperatures of 0–2°C and 60%–70% relative humidity. Because of their small size, shallots tend to pack closely so they should not be placed into deep piles. Shallots are stored in slatted crates or trays allowed good air movement in and around the bulbs. This is important to remove excessive moisture and to minimize storage diseases.

Low relative humidity and low temperatures are important to keep shallots sound and dormant and free from sprouting and root growth. At humidity much above 70% and at warmer temperatures of 5–8°C more of the shallots will sprout, develop roots, and decay. With good air flow and humidity control, shallots should store for 8–10 months (www.omafra.gov.on.ca/english/crops/facts/98-037.htm).

Understanding the current practices of shallot stakeholders in the Philippines would be the best basis of identifying the best practice and innovative ways to improve the industry. As stated by Kyo, (2003), benchmarking has established its position as a tool to improve organisations' performance and competitiveness in business life.

On the other hand, Ahmed and Rafiq (1998) argued that the central essence of benchmarking is learning how to improve activities, processes and management. These aspects of evaluation and improvement by learning from others are embedded in different forms of benchmarking regardless of the definer (e.g. Ball, 2000; Bu¨ yu¨ ko¨ zkan and Maire, 1998; Carpinetti and de Melo, 2002; Command Mathaisel, 2000; Elmuti and Kathawala, 1997; Fernandez et al., 2001; Longbottom, 2000; Prado, 2001; Watson, 1993; Yasin, 2002; Zairi and Whymark, 2000a, b).

In the Philippines, fruits and vegetables comprise a large and dynamic subsector. However, it is minor component of the agriculture sector, receiving small share of projects when it comes to improving its industry particularly on the postharvest handling and mechanization. One of the reasons for the limited projects was the lack of available information to be used as project basis. To support the government in terms of providing data on the postharvest and mechanization, this study was conducted with focused on shallot postharvest systems. Studying the current practices of the shallot industry stakeholders, and identifying the problems and constraints would greatly help the government in crafting policies and prioritizing postharvest interventions for the improvement of the shallot industry.

Hence, this study assessed the different postharvest systems and identified relevant mechanization interventions for the shallot industry in the Philippines.

METHODOLOGY

Conceptual Framework

The project adapted the value chain framework using the Value Chain Diagnostic for Industrial Development by the United Nations Industrial Development Organization (UNIDO) of 2010. Under given conditions, it permits you to understand how the industry operated and coordinate to ensure primary materials are transformed, stored, transported and reach end-consumers in certain form and quality. Value chain diagnostics looks at the existing constraints and opportunities to value chain development, which are multiple in nature. It also looks at the various effects that operations in the chain have on groups of people, e.g., with regard to poverty reduction, employment, income generation, economic growth, or environmental sustainability.

Study Sites and Data Collection

Study areas were Ilocos Norte and Ilocos Sur, the identified top shallot producing provinces in the Philippines.

Key informant interviews such as the local government officials, provincial and municipal agriculturists, shallot exporters as well as cooperative or group leaders who were knowledgeable on shallot production and marketing were tapped to gather the issues, problems and other necessary information regarding shallot production, handling and marketing.

Shallot farmers, traders, agents and exporters were gathered in focus group discussion to understand the market chains of selling shallots in the local and export markets. The major postharvest practices (i.e., farm to the market) identified in the FGDs were adapted for the case studies.

Case studies were conducted to document the current postharvest practices of the different stakeholders involved. Alongside with the documentation, measurement of the actual quantitative and qualitative losses incurred at each level of marketing chain and their possible causes were likewise done.

Site visitations of the identified existing facilities and technologies for shallot were also conducted. Information gathered were processed and analysed qualitatively. Potential interventions were proposed to improve the current industry.

Loss Measurements

Considered chains in the actual loss measurement were the major market chains observed, such as the local market and export market chains.

The research team worked backwards to identify the various types of intermediaries involved in the product handling and traced back the handling routes and places where commodities passed through and finally the origin or production area where the farmer and local trader-cooperators were identified and selected.

Two sets of cooperators each for the local and export markets were identified. Selection of cooperators was primarily based on the willingness of the different actors of the particular chain to allow the project team to conduct the handling trials while they were doing their respective marketing activities in the chain.

At each step of the route, the operations were observed, quality and losses (nature and extent, whenever possible) of the commodity were documented.

Sampling Procedure and Sampling Size

Postharvest losses were measured quantitatively and qualitatively using the procedure developed by Maranan et al. in 1996 and the BPRE and PHTRC in 2009.

1. Ten (10) 2mx2m sampling strings were randomly placed in the area to serve as sample areas.

2. Plants within the every sampling area were harvested manually. Harvested, unharvested, rotten shallots were collected and placed in sacks or plastic bags separately.
3. Harvested shallots in every sampling area were weighed as well as the unharvested and rotten shallots. Weights of these samples were recorded separately and tagged for identification.
4. Curing/drying of each shallot sample was done on the same area where the whole lot of harvest were mantled for seven to 10 days. After curing, each sample was collected and the weight recorded. The rotten/rejects were removed also noting their weight.
5. The lot of shallot harvest as well as the shallot samples were transported to the trader's ware house

Methods of Analysis

Quantitative/Weight Loss. The initial weight of the total volume marketed and the samples at the farm were noted. Final weight of the samples marketed at the wholesale level was also measured. At the farmer level, samples were returned to the lot after the quantitative analysis. The commodity marketed by the farmer-cooperator was followed through by the team until it reached the first trader level. The same procedure for quantitative/weight loss at each trader level was done for each handling point until the commodity reached the retail level.

The information on the actual loss measurement was used not only to measure losses but also to identify what improved practices and/or technology intervention were needed to improve the system.

Quantitative/weight loss was computed using the following formula:

$$\%\ weight\ loss = \frac{wi-wf}{wi} 100 \qquad (1)$$

Where:

Wf = final weight of the sample/commodity at each handling point

Wi = initial weight of the sample/commodity at each handling point

Harvesting loss. After harvesting, the research team carefully collected the un-harvested produced left in the field whether intentional or not, but which the farmer did not collect. These products were left out, by-passed, shattered or have fallen on the ground by the harvesters. After collection, weighing the commodity was done to estimate the harvesting loss using the prescribed formula.

harvesting loss (HL) =

$$\frac{Ave.\ wt\ of\ samples}{m2}\ x\ \frac{10{,}000\ m2}{ha} \qquad (2)$$

harvesting loss (%HL) =

$$\frac{harvesting\ loss,kg}{potential\ yield,kg}\ x\ 100 \qquad (3)$$

Piling Loss. Underlays such as plastic sheets or canvas were laid on the spot where the farmers or traders piled their harvested products while waiting for the next activity. If the farmer or trader is using underlay, the project team placed their underlay beneath and outside those of the farmers so the produce that were scattered beyond the farmers' were taken as losses. After piling, all the produce that were left and were not recovered or totally ignored by the farmer were manually picked and weighed.

Piling loss (%PL) =

$$\frac{total\ weight\ piling\ loss,kg}{PY(1\text{-}\%harvest\ loss)}\ x\ 100 \qquad (4)$$

Curing/Drying loss. For curing/drying loss, weights and moisture content of products were taken before and after drying trials. Portable weighing scales were used in weighing the products. Curing/Drying loss included scattered produce swept and recovered by the team after completion of the drying operation.

Drying loss (% DL) = %SB
Losses due to scattered bulbs (SB)

$$\%SB = \frac{\textit{weight of dried scattered shallots}}{\textit{weight of total dried shallots}} \; x\ 100 \quad (5)$$

All data collected from the key informant interviews to farmers/growers and traders and the postharvest losses were analysed using descriptive analysis.

RESULTS AND DISCUSSION

Postharvest Practices

Harvesting. The activity took place early at seven in the morning. A 2,500 m2 shallot farm required 11 harvesters or about 44 harvesters/ha. As observed, majority of the harvesters were women. A harvester uprooted three to four plots of the plants and made small piles of uprooted shallots within the plots. The farmer shouldered the harvesting expenses which included the snacks, labor fee and other expenses incurred during the activity (Figure 1). The harvesters finished their work at around five in the afternoon.

Hauling/Unloading. Bulk hauling of uprooted shallots was performed using a trailer attached to a tractor. Loading to the trailer and unloading in the curing area were done by two male laborers (Figure 2).


Figure 1. Women uprooting shallots and small piles of uprooted shallots within the farm, Ilocos, 2014


Figure 2. Piles of uprooted shallots for transport, Ilocos, 2014

Piling/Mantling. Two to three male laborers piled, arranged and mantled the uprooted shallots for curing. This activity started in the afternoon simultaneous with the hauling/unloading activity and ended at five in the afternoon (Figure 3).

Curing. 'Daydayan,' the local name for the open field area used to cure shallots. Shallots were cured for eight to 10 days depending on the intensity of the sunlight. In case of rains, farmers covered the shallots with tarpaulins or mats. Regularly, the farmer monitored the area for possible rains and theft. Sometimes family members had to sleep in the area to safeguard shallots from pilferage (Figure 4).

Collection/Packing. Starting at around seven in the morning, cured shallots were collected and packed in sacks. Packing did not require specific weight but sacks were filled up to the brim to maximize use of the sacks (Figure 5).

Hauling. This was done using a hand tractor with trailer which was practical on the part of the farmer because of the proximity of his place from the farm. Hauling of shallots to his place was done several times.

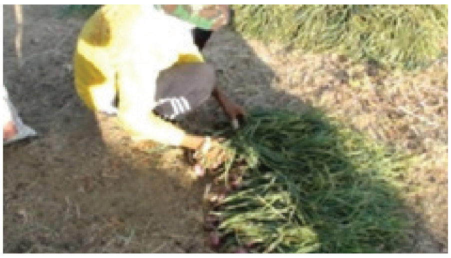

Figure 3. Piling and mantling of shallots in the field for curing, Ilocos, 2014

Figure 4. Curing shallots in 'daydayan' with stand-by tarpaulins in case of rains, Ilocos, 2014

Figure 5. Laborers collecting and sacking dried/cured shallots, Ilocos, 2014

Cleaning/Sorting/Bundling. Sixty laborers, majority were women, manually cleaned, sorted and bundled the shallots. In a day, a laborer could finish around 117 kg. They used scissors for cleaning and bamboo strips for bundling. At first, laborers bundled the shallots in small sizes (1-2 kg) piled at their sides. Then a roving male laborer made bigger bundles (5 kg) out of these small ones and packed in red mesh bags. In this area, laborers were being paid at Php2.50/kg of cleaned and bundled shallots (Figure 6).

Piling/Storage. Farmers practiced several styles of piling. Some used the Japanese style (open in the middle) while others used corn stalks in between layers of bundled shallots for aeration. The height of the piles of bundled cured shallots was about 4 feet high (including the wooden pallet). Farmers without warehouse utilized their terraces, rooms, part or their living rooms or any space for temporary storage. They usually stored their harvest for about one month or more depending on their financial capacity. While for seed purposes, shallots were de-topped and stored in red mesh bags of smaller capacity and piled in single layer on bamboo slots. Storage areas were situated in well ventilated space near the roof top (Figure 7).

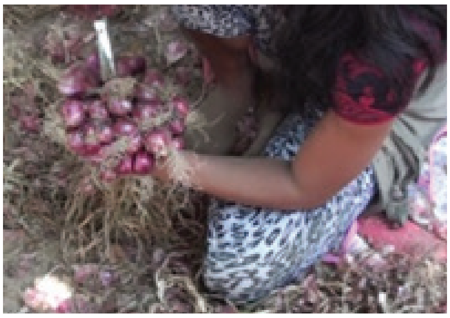


Figure 6. Cleaning, sorting and bundling of shallots before farmer's storage, Ilocos, 2014



Figure 7. Different piling and storage of shallots in the farmer's place, Ilocos, 2014

Marketing. Instead of selling to the local market, farmers waited for the exporter to buy their produce because of the higher price offered and the financial capacity to buy the whole lot of their shallot stocks unlike the local market traders. More so, exporter-buyer picked up shallot stocks from the farmers' area.

Exporter's Storage. At the exporter's warehouse, shallots were piled in bundles or in red bags stacked on pallets. It was an open-walled warehouse with hanging tarpaulins serving as walls during rains to protect the stock of shallots from being wet. Storage at the exporters' level lasted for a minimum of one month to maximum of three months (Figure 8).

Cleaning/Sorting. This activity at the exporter's level was performed when importing countries had already placed their orders. Another round of cleaning and sorting was done inside the warehouse of the exporter. Cleaners were provided with mats as underlays during the activity and crates for the sorted good shallots. They trimmed the roots by using scissors, removed foreign matters and dried leaves if the importer required cutting of leaves. However, if the importing country required shallots with leaves, dried scales and foreign matters are removed, roots trimmed and re-bundled (Figure 9).

Packing/Shipping. The cleaned and re-bundled shallots were packed in red mesh bags weighing, 8-10 kg per bag or 24 kg per bag. Importing countries had their own requirements. Some preferred shallots packed in red bags while others in crates. The product was shipped on freight–on-board arrangement using a reefer van.

Figure 8. Exporter's open-walled warehouse with piles of bundled shallot and in red bags, Ilocos, 2014

Figure 9. Cleaning and sorting of shallots using scissors, underlay and crates, Ilocos, 2014

Postharvest Losses

Three systems were observed; the shallot bundled for the local market, shallot bundled for export market, and shallot trimmed for export market.

Table 3 showed that total of 20.48% postharvest losses was incurred by the shallot local market chain. Farmers during manual harvesting incurred around 3.34% losses due to unharvested and cut bulbs left by the harvesters in the field. Traders, on the other hand, incurred around 14.71% from the cleaning, sorting and bundling activities due to rotten, leaves, sprouting, soil and rejects (the small ones used for seeds). Transporting the commodity using an open truck resulted to 2.43% loss due to moisture loss.

For the export market, there were two types of export products: shallots in bundled form and trimmed shallots dependending on the importer's preference.

Postharvest losses incurred by the export chains ranged from 28.73% (bundled) to 30.26% (trimmed).

Harvesting loss for the bundled shallot for export was at 4.84%. Similar to the local market chain, manual harvesting was employed in the bundled and trimmed shallots for the export market. Harvesting loss was due to unharvested and cut shallots which were left in the field. Higher losses were incurred by the shallot export products compared to the local product were due to the double handling of activities such as the cleaning, sorting and bundling and storage activities. Manual cleaning, sorting and bundling activities were done by both the farmer and exporter incurring 5.98% and 5.13%, respectively. This was due to rotten, leaves, sprouted bulbs, soil and rejects. Rejects were the small ones which considered for seeds in the following planting season.

Table 3. Postharvest activities and corresponding losses from bundled shallots for local market, Ilocos, 2014

Postharvest Activity	Actor involved	Percent Losses	Sources of losses
Harvesting	Farmer	3.34	Unharvested, Cut
Cleaning/sorting/bundling	Trader	14.71	Rotten, leaves, sprouted soil, rejects (for seeds)
Hauling to wholesaler/ Retailer	Trader	2.43	Moisture loss
TOTAL LOSSES		**20.48**	

Table 4. Postharvest activities and corresponding losses from bundled shallots for export market, Ilocos, 2014

Postharvest Activity	Actor involved	Percent Losses	Sources of losses
Harvesting	Farmer	4.84	Unharvested, Cut
Cleaning/sorting bundling	Farmer	5.98	Rotten, leaves, sprouted, soil, rejects (for seeds)
Storage at farmer level (21 days)	Farmer	5.17	Moisture loss
Hauling to exporter's place	Exporter	1.80	Moisture loss
Cleaning/sorting/bundling	Exporter	5.13	Rotten, leaves, sprouted
Storage at exporter level (28 days)	Exporter	5.81	Moisture loss
TOTAL LOSSES		**28.73**	

During transport, moisture loss at 1.80% was recorded because the exporter utilized an open truck in hauling the stocks.

On the other hand, storage activity which lasted 21days at farmer level and 28 days at exporter level incurred losses at 5.17% and 5.81%, respectively. As documented storage areas were open spaces which were not appropriate for storing shallot thus incurring moisture loss (Table 4).

On the other hand, for the export trimmed product, postharvest loss was higher in the cleaning, sorting and bundling on the exporter level because laborers employed trimming of dried leaves resulting to a 6.83 postharvest loss because of rotten, sprouting and trimmed leaves. Moreover, storage loss was accounted to 5.62% due to moisture loss. As described, storage facilities of exporters were open-walled building to allow good air movement in and around the bulbs but stacked at four-feet high which was not recommended (Table 5).

CONCLUSION

Insufficient supply of labor was one of the problems encountered by the actors involved in the marketing chains. Lack of postharvest facilities, market information and potential market outlets were identified problems of the different stakeholders.

Some potential interventions were on the development of small-scale onion harvester, mechanical leaf cutter and modification and adoption of foreign technologies for local use to address problems on the timeliness, insufficient manpower supply which would redound to reduced losses and costs. Curing methods and technologies to extend storage shelf-life must be studied. Moreover, development of insect and disease control for shallot storage was suggested. Trainings on best practices or GAP and on postharvest and mechanization were requested by the stakeholders.

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POSTHARVEST HANDLING SYSTEMS AND LOSSES OF EGGPLANT IN MAJOR PRODUCING AREAS OF THE PHILIPPINES

Edgar D. Flores[1], Renita SM. Dela Cruz[2], Ma. Cecilia R. Antolin[3]

ABSTRACT

Eggplant is one of the most popular lowland vegetables in the country. Like any other vegetables, however, eggplant is perishable and has a very short shelf life once it detached from the mother plant. An understanding on the existing postharvest handling practices and systems of eggplant is an important method in identifying gaps in postharvest technology to reduce losses. This paper analyzed the postharvest handling system of eggplant based on the primary data obtained from 202 eggplant farmer-respondents. Actual loss assessment in major routes of eggplant from farm to retail market was also conducted. These were the routes from Pangasinan-Pasig City market, Pangasinan-Divisoria market, and Quezon-Divisoria markets. Major postharvest problems identified for eggplant were noted including their potential technological interventions. Along the postharvest handling systems, bulk of harvested eggplants was mostly traded in Manila Central Markets such as Divisoria, Balintawak, and Pasig City. The postharvest system's loss of eggplant ranged from 4.78 to 8.05% for a period of two days from harvest at the farm to retail market level. Physiological weight loss for two days was high at the retail level at a range of 4.47 to 7.53%. In addition, quality deterioration such as shriveling also started to set in at the retail level. Reduced quality was observed at the range of 1.67 to 12.58% of the volume handled by the retailer. This qualitative loss has significant effect on the price of eggplant in the market as there is a decrease in market value as quality deteriorates. With this concern, the recommended potential interventions are the development of suitable packaging materials to reduce physiological weight loss, validation of evaporative cooling technology using bigger volume of eggplant and the evaluation of technically and financially viable surface coatings to retard transpiration and evaporation of moisture from eggplant.

Keywords: Eggplant, Losses, Postharvest systems, Qualitative, Quantitative

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INTRODUCTION

Eggplant (Solanum melongena L.)is one of the non-tuberous species of the family Solanaceae with a wide range of varieties of fruit shapes and colors, ranging from oval or egg-shaped to long club-shaped; and from white, yellow, green through degrees of purple pigmentation to almost black (Kantharajah and Golegaonkar, 2004). Eggplant fruits are known for being low in calories and rich in minerals such as potassium, magnesium, calcium and iron that are beneficial for human health (Zenia and Halina, 2008).

The average annual production worldwide of eggplant devoted to less than 2.5 million hectares is 26,532,747 t (FAO, 2014). In the Philippines, eggplant is one of the most popular lowland vegetables due to its inclusion as basic ingredients of the most popular vegetable food viand in the country called "pinakbet". Philippines ranked as eleventh producer of eggplant in the world, with an average annual production of 209, 783.40 t (BAS 2014). Among the provinces, Pangasinan and Quezon are the major producers of eggplant, contributing 30 and 13% share of the total Philippine eggplant yield output, respectively.

Like any other crops, eggplants are also exposed to postharvest losses during harvesting and transportation from farms to market. These losses are mainly due to physical damage, weight reduction and improper postharvest handling systems that led to both qualitative and quantitative losses. Freshly harvested eggplant have high respiratory rate that releases both heat and moisture that would eventually soften its texture. Eggplant is highly perishable because once it detached from the plant it can no longer be stored for a long period of time. Ozcan (2007) mentioned that losses occur during harvest, preparation for market, transportation of fruits and vegetables vary from 15 to 50%. Under Philippine situation, postharvest losses in fruits and vegetables could be up to 50% (Nuevo and Apaga, 2010).

Postharvest loss is a measurable quantitative and qualitative loss of a product at any moment during the postharvest chain. It includes the change in the availability, edibility, wholesomeness or quality of the food that prevents its consumption (Troger et al. 2007). Both quantitative and qualitative food losses of extremely variable magnitude occur during postharvest stages, from harvesting, handling, storage, processing and marketing, to final delivery to the consumer. It was reported that improper postproduction practices result in losses due to spoiling of the product before reaching the market, as well as quality losses such as deterioration in appearance, taste and nutritional value. Such improper practices risk the quality of the product for market, reduce the prices and storage period of the products (Turan, 2008 as cited by Buyukbay et al. 2011).

With this, it is important to know and understand the existing handling practices, problems and concerns of the eggplant's stakeholders to identify gaps in postharvest technology. An assessment of the quantitative and qualitative losses has to be established to serve as basis in formulating loss reduction program and development of control measures and interventions that are appropriate, efficient and with high reduction impact in the handling system of eggplant.

This study aimed to establish baseline information on the postharvest handling systems and losses of eggplant as basis for developing and providing appropriate and viable postharvest technologies.

Specifically, it aimed to:

1. Identify and characterize the postharvest handling systems of eggplant from the farm to the market;
2. Determine the quantitative and qualitative losses at major points in the postharvest handling system of eggplant; and
3. Identify problems and constraints in postharvest handling of eggplant and their potential interventions.

METHODOLOGY

Data Collection and Analytical Tools

Data and information were collected through desk research, key informant interviews (KII), survey and focus group discussions (FGD). Interviews were done with 202 eggplant farmers and other stakeholders who are very familiar, knowledgeable and immersed in the production, postproduction and marketing activities of eggplant. They include key officials of Department of Agriculture (DA), local government units (LGUs) and traders (i.e. wholesaler, retailers, viajeros, agents/middlemen). Visits were done in the LGUs to determine the major growing areas. Surveys and FGDs were conducted in top producing municipalities with each three top producing barangays. A minimum of 10 farmers/growers or 10% of the total farmers in each top producing barangay were gathered and interviewed using structured questionnaires. Among the information gathered were the production, postproduction and marketing practices of eggplant famers/growers, estimated losses as perceived by farmers and the possible causes of losses in each operation. The information generated and the commodity flow established was served as input for the selection of study area for loss assessment studies.

Actual loss assessment

Loss assessment studies for eggplant were conducted in first two highest producing provinces of Pangasinan and Quezon where majority of crop is grown for commercial market. Prior to the conduct of this study, KII was first done with barangay officials, farmers and traders to determine who among the farmers had schedule of harvests of eggplant during the period of study. An arrangement on how the study would be conducted was explained to the selected farmer-cooperators and trader-cooperators. Concurrently, an interview was done on the production, postproduction practices and market destinations of the crop. Postharvest losses were measured using the procedure developed by BPRE and PHTRC in 2009 (Paz, et al. 2009).

Loss assessment were done following three to four routes, treating the routes as replicate for a given postproduction operation. The assessment of postproduction losses of eggplant (both qualitative and quantitative) began from farm to retail level. The actual operations, practices and facilities used in handling the commodity were observed and noted.

Ambient conditions such as temperature, relative humidity (RH), where the crops are exposed were also monitored. The distance traveled, nature of the road network, the time required to harvest and transport the commodity from farm to market, losses due to mechanical, physical and physiological damage and weight loss due to moisture reduction were determined. The commodity handlers such as farmers, traders, wholesalers, and retailers were also interviewed to determine related information such as price and market quality standards.

Qualitative losses are due to physiological changes that make the appearance, taste or texture of the produce less desirable to the end users. Visual quality rating (VQR) and quality profile (QP) were used in determining the quality loss.The evaluation quality in the losses was performed at the determined points of the commodity flow. VQR refers to the physical attributes of the commodity as affected by handling or mechanical damage during harvest and handling operations. Five to 10% of the stocks were subjected to VQR. Samples in each container were labelled and rated by trained staff in every operation from farm to the final destination. The VQR scales and its description are summarized in Table 1 while the quality traits in describing the quality profile of eggplant from farm to retail level are presented in Table 2. The average rating for the samples monitored is calculated using equation 1.

$$VQR = \frac{(Wc)(Rc) +.. (Wc)+(Rc)}{\textit{Total weight of the samples}} \qquad (1)$$

Where: Wc = weight of the commodity per rating scale;
Rc = rating of the commodity

Quantitative losses are due to the reduction in weight (e.g. spillage, moisture loss, etc.) of the total produce from different points of the commodity flow. The measurements of losses are determined from weight differences of the initial and final weight of the whole stock produce. The following equations were used in the computation of loss at each handling point:

Harvesting loss (HL) – these are the eggplant that were left in the farm unaccounted during harvesting activity. Harvesting loss is the ratio of the total weight of uncollected or left marketable crops at the farm by the total weight of marketable produce multiplied by 100. It is calculated using equation 2.

$$HL\,(\%) = \frac{UCMh}{CMh+UCMh} \times 100 \qquad (2)$$

Where UCMh is the uncollected marketable commodity during harvesting; and CMh is the collected marketable commodity during harvesting.

Sorting loss (SL) – these are the marketable eggplants that were accidentally sorted as non-marketable rejects. This can be a combination of big, medium and small sizes of eggplants. It is calculated using equation 3.

Where ASRs are eggplants accidentally sorted as rejects; and SMCs are eggplants sorted as marketable commodity.

$$SL\,(\%) = \frac{ASRs}{SMCs+ASRs} \times 100 \qquad (3)$$

Nonmarketable rejects (NR) – These are composed of edible and non-edible rejects. Edible rejects are those eggplants slightly damaged with visible bacterial specks and with low physical quality caused by pre-harvest-related defects that cannot be accepted in the market standard. Non-edible rejects are non-edible eggplants totally damaged by bacteria or (fruit borer) and pre-harvest-related defects that cannot be accepted in the market standard. It is calculated using equation 4.

$$NR\,(\%) = \frac{NRs}{SMCs+NRs} \times 100 \qquad (4)$$

Where NR is the non-marketable reject; NRs is the sorted non-marketable commodity reject during sorting; and SMCs is the sorted marketable commodity.

Table 1. Rating scale used in VQR of samples for eggplant

Scale	Description
5	Excellent condition, fresh, minor defects (which will include insect infestation, physical damage, injury)
4	Fair moderate defects
3	Minimum level of marketability
2	Minimum limit of edibility
1	Non-edible

Table 2. Quality traits used in describing QP of eggplant

Pre-harvest losses	Postharvest losses		
	Mechanical damage	Pathological defects	Physiological defects
Immature	Deep dents	Soft rot	
Sunscald	Compression damages	Wilting	Shrivelled
Curled	Bruises	Signs of disease	
Overmature	Punctures		
Double	Cuts		
Wind scar	Cracks		
Healed crack			
Insect damage			
Snail damage			

Weight loss (WL) – loss that contributes to the reduction of weight or volume during the operations from harvesting up to the point of sale to the consumer and calculated using equation 5.

$$WL\ (\%) = \frac{IW-FW}{IW} \times 100 \qquad (5)$$

Where WL is the weight loss in percent; initial weight (IW) and final weight (FW) are the sample weights before and after a period of observation, respectively. Period may refer to time or operation.

The actual assessment of losses (quantitative and qualitative loss measurement) was done from harvest to retail level. The actual operations, practices, and the available postharvest technologies used in the handling of the produce were also observed and noted. The exposure of the crop to the climatic conditions, temperatures and relative humidity (RH), were also monitored. The commodity handlers; farmers, traders, wholesalers, and retailers were also interviewed to determine the current practices on handling the crop, price and the situations that cause changes, and the market quality standards.

Method of Analysis

Data and information collected from the key informant interviews, surveys and FGDs were analyzed with the aid of Statistical Package for Social Sciences (SPSS). Qualitative and quantitative losses were presented using mean values.

RESULTS AND DISCUSSIONS

Postharvest Handling Systems of Eggplant

Harvesting. Eggplant farmers from Pangasinan and Quezon provinces used similar maturity indices. Majority of respondents (85%) harvested their eggplants based on the number of days or maturity days. Other farmers (48%) also harvested their eggplant based on size of the fruit. Eggplant is normally harvested 45 to 60 days after transplanting and has attained a certain size. Other harvesting indices considered were breakage in the calyx and glossy purple in color (Table 3). Both provinces have the same methods of harvesting.

In Pangasinan, picking of eggplant was done by bare hands and using bamboo basket and/or crates and sacks as in-field containers (Figure 1). Others also used crate as a container while picking. In Quezon, eggplant fruits were temporarily put on the ground along rows, after which, hauling was done when picking has been completed. Majority of eggplant farmers (95%) preferred to harvest in the morning. Harvesting was done as early as 5 AM to 10 AM, depending on the area of production. About 8 to 10 harvesters a day were needed to harvest one hectare of eggplant. Hired laborers are paid either in per kilogram, per container or daily basis. In Pangasinan, a picker was paid Php 200 per day while in Quezon, a laborer is paid at Php 2 to 3/kg of harvested eggplant.

When the price of eggplant is too low, the eggplants were no longer harvested by the farmers, considering that the cost to be incurred for labor and transport are greater than the gross sale. Harvesting is done in a staggered basis. For the entire cropping season harvesting was done for 25 to 35 times.

Hauling. Most of the farmers manually hauled their harvested eggplants to a temporary shed where sorting, washing and packing are done (Figure 2).

Harvested eggplants were carried manually when sorting, washing and packing are done in the farm. However, if these were done in farmer's house, hauling was done by using cart, tricycle or hand tractor with trailer. In Pangasinan, labor for hauling was paid Php 200.00/day while its counterpart in Quezon was paid Php 2 to 3/kg of harvested eggplant.

Sorting. While harvesting, all picked eggplants were hauled to a temporary shed in the farm or near the house of the farmer for sorting, cleaning and packing. Depending on the proximity of the production farm to the packaging shed, about four to six persons were required to haul a batch of harvest in one hectare area. After hauling, sorting was done in the packing shed located within the farm or near the farmer's house (Figure 3). Most of the farmers sorted their produce according to quality (88.12%) and size (75.74%). Fruits which were over-mature, with insect pest and diseases were considered rejects. Those eggplants that were infested minimally by pests but still edible were packed separately and sold at lower price or sometimes given to the laborers.

Washing. All of the farmer-respondents of both provinces practiced washing with water before packing. Washing of eggplant is done by dipping in water to remove surface dirt around the fruit (Figure 4). The eggplant was removed from water immediately and packed in polyethylene (PET) plastic bag without removing surface water.

Figure 1. Manual picking eggplant and using bamboo basket as in-field container

Figure 2. Manual hauling eggplant from farm to farmer's house

Figure 3. Manual sorting of eggplant near the farmer's house

Figure 4. Washing of eggplant by dipping in water

Packing. Generally, eggplants were packed in polyethylene (PET) bag (Figure 5). Those classified as "good" and "semi-good" are packed in 10-kg while rejects (RR) are packed in 15 to 20 kg weight basis. Packing materials (PET bags) were usually provided by the farmers but there are some cases where the plastic bags are provided by the buyers, depending on their market arrangement. Packaging material costed Php 3.00 to Php 4.00 per piece. In Quezon, where the eggplant was brought to Sentrong Pamilihan ng Quezon in Sariaya, Quezon,the eggplant was packed in PET bags labeled with "Sentrong Pamilihan ng Quezon". The PET bags had dimensions of 20 x 30 inches and thickness of 0.00125 gauge. About six to 8 persons were required to sort and pack one batch of harvest from one hectare area.

Transport. Eggplants in Pangasinan (Villasis, Asingan and Manaoag) were brought to Villasis or Urdaneta Market using tricycles or jeepneys which take 30 to 45 min. Elf trucks or jeepneys were used in transporting eggplant to Divisoria and Pasig markets which usually takes 4.5 to 6 h from Urdaneta market. Eggplants from Quezon were transported to Sentrong Pamilihan ng Quezon or to Tanauan market using jeepneys and tricycles requiring travel time of 45 minutes to one hour. Eggplants to Divisoria market were transported using elf trucks or jeepneys with travel time of 3.5 to four hour travel. Majority of eggplants from the study areas (Pangasinan Province and Quezon Province) were transported using jeepneys from farm to trading post markets in Urdaneta City, Tanauan City and Sentrong Pamilihan ng Quezon (Figure 6). Transportation of eggplants from farms to these markets usually took half to one hour of travel. Two persons were required to do the loading and unloading of a jeepney load of eggplant, 40 to 50 packs of 10-kg in 0.5 h.

Figure 5. Packaging of eggplant using polyethylene (PET) bag

(a)

(b)

Figure 6. Transportation of eggplants (a) to local market and from (b) local to commercial market

Table 3. Postharvest handling practices of 202 eggplant farmers in Pangasinan and Quezon, 2014 (% reporting)

Operation	Pangasinan n=124	Quezon n=78	All Provinces n= 202
Harvesting			
Maturity indices			
No. of days	94.35	69.23	84.65
Color of fruits	0.00	14.10	5.45
Size of fruits	41.94	56.41	47.52
Others: breakage on the calyx	0.00	43.59	16.83
Harvesting method			
Picking using hands	100.00	100.00	100.00
Indicative time of harvest			
Morning	100.00	87.18	95.05
Whole day		12.82	4.95
Container used*			
Sacks	32.26	74.36	48.51
Crates	0.00	15.38	5.94
Bamboo basket	38.71	0.00	23.76
Hauling (to sorting area)			
Carried by human	100.00	100.00	100.00
Washing			
Washing with water	100.00	100.00	100.00
Where done?			
Farm	100.00	100.00	100.00
Sorting/Grading*			
Size	69.35	85.90	75.74
Quality	100.00	69.23	88.12
Packing			
Container used			
Plastic (PE)	100.00	100.00	100.00

Marketing. Eggplants from the farm in Pangasinan were either sold to traders situated at trading post by the farmers themselves or picked-up by the traders at the farm. Of the total eggplant produced in Pangasinan, majority (80%) were traded and brought to Metro Manila (Divisoria, Pasig and Balintawak), 5% in Ilocos Region and 5% also in Baguio City. Only 10% of the produce went to the local market (Figure 7).

Overall, 70% of the produce from the farm was first brought to Urdaneta or Villasis markets by farmers or assembler- wholesaler-retailers before its final distribution. The remaining 30 % was directly distributed by some assemblers-wholesalers.

In Pangasinan, farmers/growers are paid either in cash-on-delivery basis and/or paid later after the eggplants have been sold by the traders. The farmgate price of eggplant in Pangasinan during peak months of June to October was as low as Php5.00/kg and as high as Php60.00/kg during lean months of December to January. The prices of “good” and “semi-good” eggplants differed by Php3.00 to Php 5.00/kg.

Retail price per kilogram ranges from PhP5.00 to Php40.00 for the common variety (morena, fortuner, casino, etc.) and from Php20.00 to Php60.00 for the native varieties. There was Php3.00 to Php5.00/kg price difference between farm price and wholesale price, and about Php5.00/kg between wholesale and retail price.

Retailers usually added Php5.00/kg to Php10.00/kg mark up. Retailers paid the wholesaler-retailers in cash. Retailers handling small volume can dispose all their eggplants with no spoilage almost every day. Retailers also paid a transport fee of Php1.50/kg and a market fee at Php250.00 for the stall. Since volume of eggplant handled by the retailer every day was 100 kg, the market stall fee for eggplants is estimated at Php2.50/kg.

Eggplants from the farm in Quezon were brought by the assembler-wholesaler-retailer or the famers to Sentrong Pamilihan ng Panlalawigang Agrikultura ng Quezon (SPPAQ) or Tanauan City Market in Batangas. From Tanauan City Market or Sentrong Pamilihan ng Quezon, the eggplants were traded to Manila Market (e.g. Divisoria, Balintawak, Pasig) by the truckers/viajeros, and to local markets or other markets in nearby provinces. Retailers in Manila market or other markets from nearby provinces purchased eggplant in Divisoria and sold it to household consumers.

Of the total eggplant produced in Quezon, about 62% went to Metro Manila (Divisoria, Balintawak and Pasig), 14 % to Cavite, 12% to Bicol region, 7% to Laguna province and about 5% was traded locally.

Overall, 54% of the produce from the farm were first brought to Sentrong Pamilihan ng Panlalawigang Agrikultura ng Quezon (SPPAQ), 19% to Tanauan City market and the remaining 27% was directly brought and distributed by assembler-wholesaler to their markets (Figure 8).

In Quezon, eggplant farmer-sellers were paid in cash. The farm gate price of eggplant during peak months of April to May was as low as Php4.00/kg and as high as Php50.00/kg during the lean month of December. As in Pangasinan, the price difference between farm price and wholesale price was Php3.00 to PhP 5.00/kg and about Php5.00/kg between wholesale and retail price. The assembler-wholesaler-retailer normally set the farmgate price and retail price. Farmers were often paid in cash upon delivery.

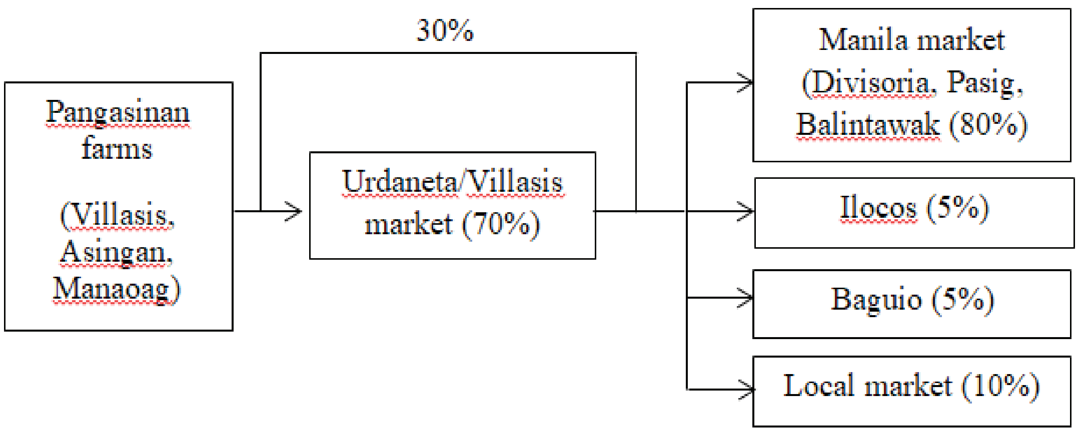

Figure 7. Geographical flow of eggplant in Pangasinan, 2015

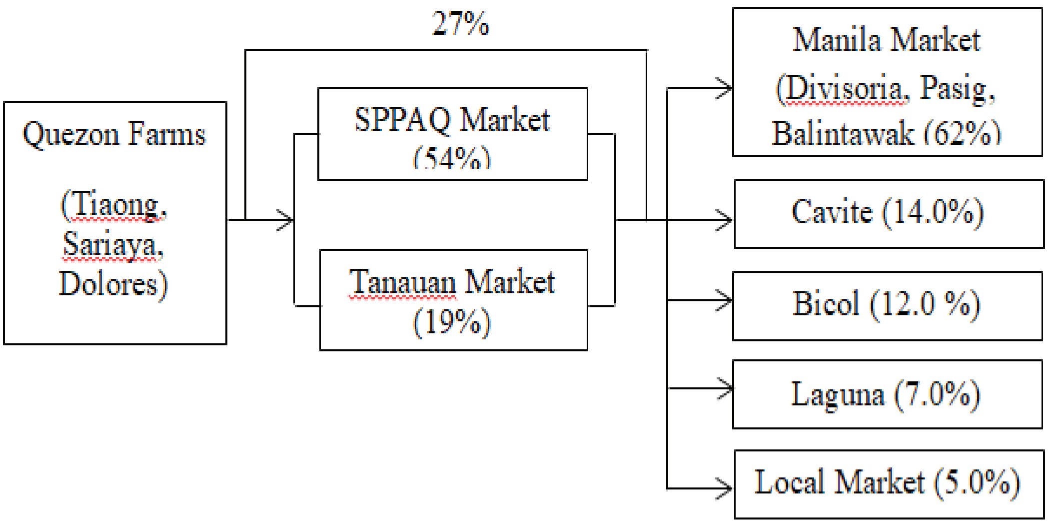

Figure 8. Geographical flow of eggplant in Quezon Province, 2015

Quantitative and Qualitative Loss

Table 4 summarized the percentage of losses in eggplant during the actual loss assessment from farm to retail level. Quantitative and qualitative lossed were recorded and noted as the eggplant was transported from the custody of farmers to the subsequent stakeholders.

Results revealed that the total postharvest system's loss ranged from 4.73 to 8.05% (average of 5.83%) from the farm to retail, two days after harvest (2DAH). This system's loss was mainly contributed by weight loss (moisture loss) from farm to the retail level. Across the routes evaluated, highest postharvest loss was observed at the retail level with 4.47 to 7.53%, 2 DAH. In addition, quality deterioration such as shriveling also started to set in at the retailer level. Reduced quality was observed at the range of 1.67 to 12.56% of the volume handled by the retailer. There was a decrease in market value as quality deteriorates.

Aside from quantitative loss, the quality of marketable eggplant from farm until its disposal at the retail market was monitored. About 10% of the total volume of good quality eggplant for trading was subjected to VQR and QP at different handling points [e.g., farm to trading post, from trading post to Manila markets (Divisoria, Pasig, Balintawak), to retail markets].

The VQR of eggplant was assessed at specified handling point using the developed quality rating for eggplant ranging from (1 as poor quality) to (5 as excellent quality).

For Pangasinan-Pasig route, the VQR of eggplant at the farm level was 4.32 and declined to 3.90 upon reaching Urdaneta City Market. VQR further decreased to 3.28 at the retail level 2DAH (Figure 8). Preharvest defects caused by shoot/fruit borers, curled and windscar were noted at the farm level. Postharvest defects such as dents, cracks/cuts, bruises, punctures and compression damage were also observed but found minimal. These defects increased as the eggplants transported to Urdaneta City and Pasig markets. Despite the reduction quality ratings and the observed defects, the eggplants were still acceptable in the market. Physiological defect such as shrivelling was first observed one day after harvest (1DAH) at the retail level and increased further 2DAH. Though the samples of eggplant were disposed immediately 2 DAH at the retail market, some samples had reduced market value due to shriveling.

Table 4. Quantitative and qualitative loss, Pangasinan and Quezon, Philippines, 2015

Route	Farmer Level	Assemble/Wholesaler Retailer (Market 1)	Wholesaler/Retailer (Market 2)	Retailer (DAY1-2)	Total Sys Loss
1. PANGASINAN-PASIG					
Postharvest					
Quantitative loss (%)	nil	0.35	0.17	7.53	**8.05**
Qualitative loss (%)	nil	nil	nil	6.05	
2. PANGASINAN-DIVISORIA					
Postharvest					
Quantitative loss (%)	nil	0.21	0.05	4.47	**4.73**
Qualitative loss (%)	nil	nil	nil	1.67	
3. QUEZON-DIVISORIA					
Postharvest					
Quantitative loss (%)	0.44	0.09	0.08	5.15	**5.76**
Qualitative loss (%)	nil	nil	nil	12.56	

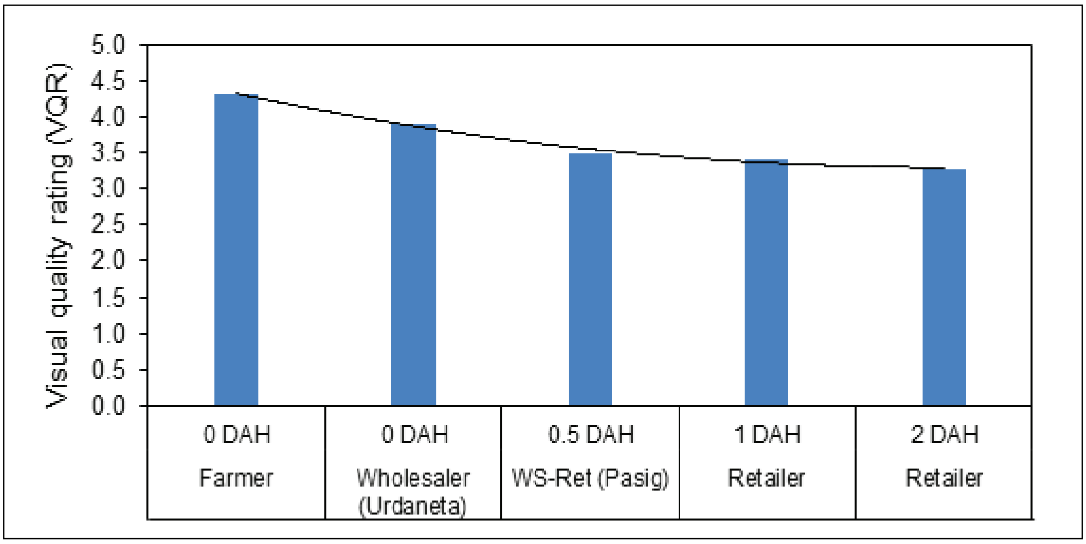

Figure 8.VQR of eggplant in Pangasinan-Pasig market route; 2015

For Pangasinan-Divisoria route, the same trend of defects was observed as in the case of Pangasinan-Pasig market route (Figure 9). VQR at the farm level was relatively higher at 4.87 than Pangasinan-Pasig route, indicating better quality of harvested eggplants. Minor mechanical defects such as dents, bruises and punctures were noted after transporting to Urdaneta market and Divisoria. Physiological defects like shriveling was noted on the second day at the retail level where about 2% of the volume handled by the retailers had reduced market value.

For Quezon-Divisoria route, VQR at every handling point also decreased until it reached the retail level (Figure 10).

Mechanical defects due to compression during handling and transporting were also noticed. There was an increased degree of shriveling and rotting and reduced the quality of eggplant at the retail level.

In summary, the results of profiling indicated that most of the defects at farmer level were due to preharvest factors specifically caused by pest and diseases. Minor postharvest defects such as bruising, compression, and dents were observed at the wholesaler and wholesaler-retailer level after transporting. However, the effects of mechanical and physiological factors contributed to quality deterioration of eggplant which was observed at the retail level.

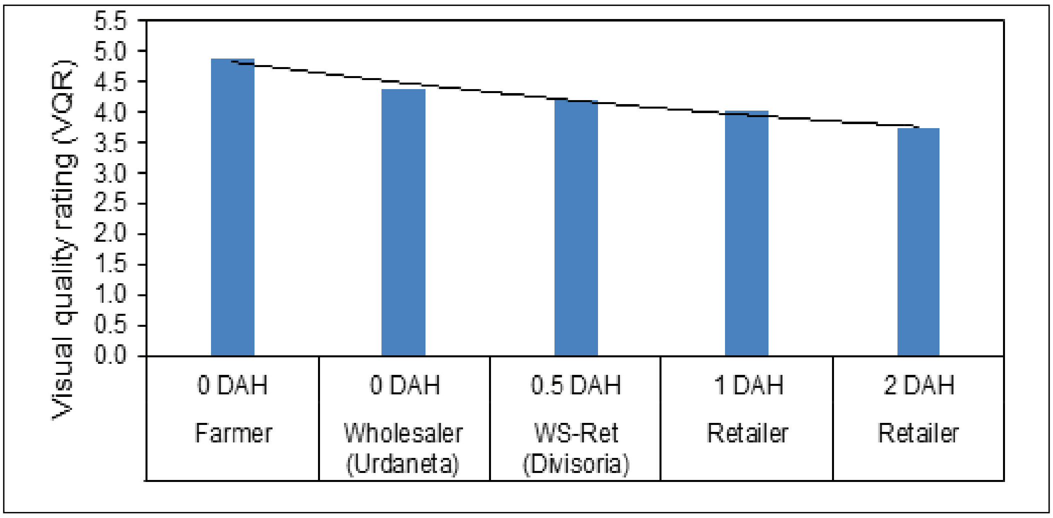

Figure 9. VQR of eggplant; Pangasinan-Divisoria market route; 2015

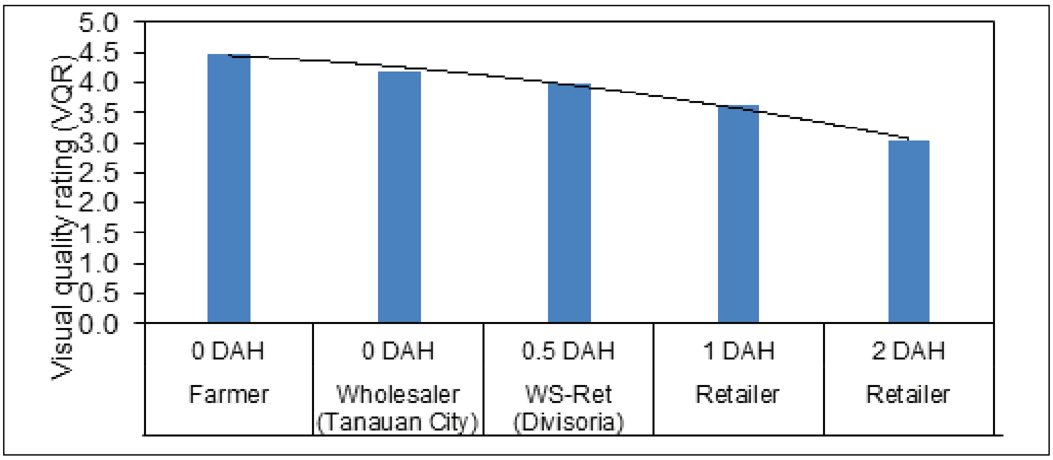

Figure 10. VQR of eggplant in Quezon-Divisoria market route; 2015

Table 5. Problems or inefficiencies in eggplant industry and their potential interventions, 2015

Existing Practices	Problems and constraints	Potential interventions	
	Problems	**Available Technologies**	**Potential Intervention**
Sprinkling/wetting the eggplant with water is the usual practice of farmers and traders to prevent eggplant from shriveling or making it dull even for a short period of time.	Weight loss due to is moisture loss in eggplant about 4.47 to 7.53% .	Cold storage can prolong shelf life of eggplant with recommended temperature and relative humidity.	Development and improvement of existing systems/ technologies to prolong the shelf life eggplant
Eggplant is perishable and has short storage life. Quality losses occur more on the part of the traders most especially during peak season. Traders must sell their eggplant stock on a day or two to recover their capital and realize income.	Shriveling with minor defects due to moisture loss ranged from 1.67% to 12.58%	Evaporative cooling storage system was reported to reduce weight loss of eggplant by at least two-fold compared to open storage (ambient condition).	Evaluation or validation of some surface coatings to retard the transpiration/evaporation of moisture from eggplant. Validation of evaporative cooling technology using bigger volume of eggplant.

Problems and constraints of eggplant production and their potential interventions

Based from the results of survey and postharvest loss assessment conducted, the problems and constraints of postharvest handling system of eggplant with their potential interventions were drawn and presented in Table 5.

CONCLUSIONS AND RECOMMENDATIONS

The study focused on the postproduction operations of eggplant. Quantitative and qualitative losses at major postharvest handling points were determined. Some major constraints in eggplant production was identified and potential interventions were formulated. As results, bulk of harvested eggplants was mostly traded in Manila central markets (Divisoria, Balintawak, and Pasig). Postharvest loss in eggplant ranged from 4.73 to 8.05% which largely contributed by physiological weight loss (moisture loss) especially at the retail market level. Among the major handling points, physiological weight loss for two days was high at the retail level at a range of 4.47 to 7.53%. Likewise, quality deterioration such as shrivelling also started to set in at the retail level. Reduced quality was observed at the range of 1.67 to 12.58 % of the volume handled by the retailer.

With this concern, the recommended potential interventions were the evaluation of technical, environmental and financial viabilities of surface coatings to retard the transpiration/evaporation of moisture from eggplant, research and development of suitable packaging materials to reduce physiological weight loss (e.g. use of films, biological surface coatings, etc.) and validation of evaporative cooling technology using bigger volume of eggplant.

The information generated from this study can be used by the government/policy makers in providing appropriate postharvest and mechanization technologies to improve the eggplant industry of the country.

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DEVELOPMENT OF COMMERCIAL AND INDUSTRIAL PRODUCTS FROM CACAO SWEATINGS

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ABSTRACT

Cacao beans must be fermented properly to produce good quality cacao beans for marketing and processing into various products and applications. Previous studies found that unfermented cacao beans produce less chocolate flavor. In the traditional practice of fermentation which uses wooden fermentation box, by-products are not edible with foul odor, creating air and water pollution. The study attempted to collect food grade sweatings using the stainless fermentary box. The sweatings were processed into wine, vinegar, ethanol and health drink. The products were characterized regarding physicochemical properties, nutritional and proximate analysis.

Results showed that UF18 cacao clone had the highest produced sweatings with a mean value of 862 ml. The cacao sweatings had an average pH of 4.67, which can be characterized as weak acid while its total soluble solids had an average of 13.5 oBrix that can be used for the production of beverage products such as health drinks, vinegar, wine, ethanol and among others. The processed cacao wine contained alcohol (10-12%), pH (3.0-4.0), and total titratable acidity (≤1.0); The Total Soluble Solids (10 oBrix), alcohol of (3-5%), pH (2.95-3.02), and total titratable acidity (4-5%) obtained in vinegar conforms with the Philippines legal standard. The processed health drinks contain a total soluble solids (15oBrix), pH (3.95- 4.5) and total titratable acidity (≤ 1.0%). Cacao health drink is a good source of Vitamin B1, potassium and magnesium. At the same time it contained low sodium and zero fat. The processed cacao wine had an ash content of 0.335%, total acids (0.758%), fixed acids (0.516%), volatile acids (0.242%), specific gravity (0.998), ethyl alcohol (12.6%), and n-Propyl alcohol (12.8%). Cacao vinegar had a total solids of 5.79%, ash (0.159%), alkalinity (0.253 ml), non-volatile acids (0.492%), total titratable acidity (5.36%), total soluble solids (8.29 ^{o}Brix), non-volatile reducing substances (3.31%) and permanganate oxidation number (13.1).The microbial load (e.g. aerobic plate count, yeast and molds, total viable count, e-coli) of cacao sweatings, wine, vinegar and health drinks obtained a value of <1 cfu/ml which is compliant with the standard safety level set by USDA.

Keywords: Cacao sweatings based products, Cacao sweatings, Nutritional and proximate analysis physic-chemical properties

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INTRODUCTION

Cacao (Theobroma cacao L.) is one of the most important beverage crops, next to coffee and tea. It is major agricultural commodity traded worldwide. It is considered as a cash crop for growing countries and a key import for processing and consuming countries. It is also consumed as chocolate confectionery, chocolate coated products such as biscuits, ice cream, or in other food products containing cocoa powder including cakes, snacks.

World Cocoa Foundation (2012) reported that the world production of cacao continues to increase in absolute terms from 3.66 million metric tons in 2007-2008 to 3.98 million metric tons in 2011-2012. On the other hand, Food and Agriculture Organization reported that the world production of cacao in 2016 was 4.47 million metric tons planted in 10.2 million hectares. Africa is the principal cocoa producer with 63.3 % market share or a total of 2.5 million metric tons concentrated mainly in Ghana and Ivory Coast. Asia and Oceania, on the other hand contributed about 18.8 % of the total world production or about 718,000 tons, the bulk came from Indonesia (602,000 tons) (FAO, 2017).

With the increasing consumption of chocolates worldwide, global demand for this commodity had been exceeding the global supply. Netherlands is the top importer valuing to 2.076 billion USD in 2009 (FAOSTAT, 2012). Also, demand is growing more rapidly in Asia where strong economic growth, particularly in India and

China is resulting in more people being able to afford luxury foodstuffs such as chocolate (Sunstar Davao, 2012).

The cacao production in the Philippines shows a potential for expansion since the country is ideal for cacao growing particularly in Mindanao. For instance, about 2 million hectares planted with coconut is "highly suited" to be intercropped with cacao. In 2012, the Philippines produced around 4,831 metric tons of cacao, the bulk coming from the Davao Region with 3,763 metric tons of production (BAS, 2013). The initiatives to intensify and revive the local cacao industry have been started through the efforts of the government, international organizations and private entrepreneurs, Cocoa Foundation of the Philippines (CocoaPhil) in particular by developing a Cacao Roadmap. As emphasized in the roadmap, a production of 100,000 tons of cacao in one cropping season is included in their vision.

Cacao beans are primarily used in chocolate processing. However, the entire processing operation generates a substantial quantity of waste such as sweating, pod/ husk, and hull, which are good material for the production of alcohol beverages, vinegar, sweetener or syrup, adsorbent, and potential sources of pectin and other natural agents (Chan et al, 2013). The juice or sweating has been successfully used in Brasilia for alcoholic beverage and vinegar (Samsiah et al. 1991). However, previous studies claimed very limited or lack of complete and detailed information about chemicals and physical characteristics of the indicated derivative products (Anvoh et al. 2009).

Traditionally, the cacao processors prefer to collect the cacao beans only leaving the cacao pods in field unutilized. During the fermentation process, the wet beans are placed in wooden fermentation boxes located at the processing plant and kept for five to six days before drying. These shallow boxes are made of mahogany planks raised from the ground with slated flooring to allow sweating to drip. Two fermentation boxes with bean capacity of 500 kilogram are arranged in cascading fashion with fresh unfermented cocoa beans loaded at the upper box.

After two days, turning is done by lifting the removable planks on the front side of the upper box and unloading the beans to the lower box. The bean on the upper portion is unloaded first and the bottom beans unloaded last. The sweating or 'fermented juice' flows directly to the ground, which produces a foul odor and eventually causes air and water pollution if not properly handled and disposed of.

An alternative process and technique in collecting food grade sweating intended for processing into usable products like wine, vinegar, alcohol and health drinks is necessary. Utilization of cacao sweating, which is considered "waste" will help address the problem of waste disposal and other environmental concerns.

The general objective of the project was to utilize the cacao sweating as raw material in the production of wine, vinegar and health drinks.

METHODOLOGY

Sources of cacao pods

Five cacao clones such as UF18, BR 25, UIT, K1 and K2 were obtained from the local farms at Maligatong, Baguio District, Subasta, Tamayong, Calinan and Talandang, Davao City. There were used in the experiment. The cacao pods were manually harvested using a pruning device and transported to CocoaPHil, Talandang, Davao City for pre-processing activities.

Pre-processing of Cacao Pods

The cacao pods were washed with potable water accompanied with brushing and rubbing to remove dirt and debris. The pre-cleaned cacao pods were soaked in chlorine solution at chlorine-water ratio of 150:25 ml for 15 min, rinsed with cleaned water. The cleaned pod husks were placed in a slotted container to facilitate the air drying and dripping of water.

Extraction of cacao sweatings

The disinfected cacao pods were cut horizontally without damaging the beans using a mechanical splitter (Fig. 1). After splitting, the wet beans were manually scooped and placed in a food-grade fermentation box. The said fermentation box is made of stainless steel. It is equipped with a funnel type collector for the easy collection of sweating without interfering the fermentation process (Fig. 2a). The use of a stainless fermentation box ensures the collection of food-grade sweatings from cacao beans.

During the fermentation process, the volume of sweatings was measured and recorded every hour.

After four hours of fermentation, the accumulated cacao sweating was collected and filtered using mesh no. 24 (0.7 mm) muslim cloth to remove mucilage and undesirable solids (Fig.2b).

Physicochemical Properties of Cacao Sweatings

The physicochemical properties of cacao sweatings were evaluated regarding pH, total soluble solids (TSS), total titratable acidity and density.

Determination of pH. The pH of the samples were measured directly using pH meter (EZDO, Model No. 6011A). The pH meter was calibrated with pH 4.0 and 7.0 buffer solution.

Determination of Total Soluble Solids (TSS). Total soluble solids were determined using a digital refractometer (Sper Scientific, Model No. 3035). Results were recorded as degree Brix (°Bx).

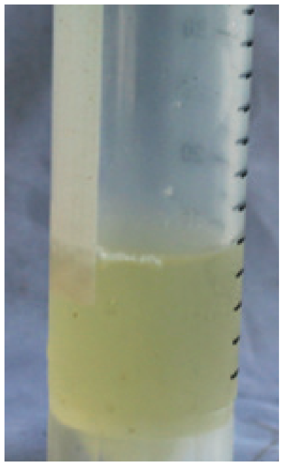
Determination of Total Titratable Acidity. The titration was determined by taking exactly 10 ml of the sample into Erlenmeyer flask. Three drops of phenolphthalein indicator was added to the sample in Erlenmeyer flask and stirred and titrated with 0.1 N of sodium hydroxide. Total titratable acidity was calculated using:

$$\text{Total Titratable Acidity (\%)} = \frac{\text{Volume of NaOH used (ml)} \times \text{Normality of NaOH} \times 0.06}{\text{Weight of sample (g)}}$$

Determination of Density. The density of the sample was determined by dividing the weight by the volume of the samples. The weight of the samples was measured using analytic balance (OHAUS Pioneer Analytical Balance).

Figure 1. Mechanical cacao pods splitter

(a)



(b)

Figure 2. Stainless fermentation box (a) and filtered cacao sweatings (b)

Production of Cacao Sweatings Based Products

The production optimization of the three cacao sweating-based products (e.g., wine, vinegar, and health drinks were undertaken) at PHil-Mech Laboratory, Munoz Nueva Ecija and CocoaPhil, Talandang, Davao City.

Cacao Health Drinks. Figure 3 shows the process flow in the production of cacao health drinks (Adomako et al., 2006). The cacao sweatings collected from the stainless fermentation box was diluted with distilled water. The initial sugar content or total soluble solids of cacao sweating were determined using a digital refractometer at ambient temperature. Refined sugar was added to attain the desired level of total soluble solids of cacao substrate.

Also, citric acid, sodium benzoate and sodium metabisulfite were added to maintain the quality and extend the shelf life of the product. Filtration of the substrate was done after adding preservatives to remove all undesirable entities. The formulated cacao health drinks was pasteurized at 90oC for 15 sec using a sterile double boiler. The pasteurized cacao health drink was cooled down and carbonated followed by filling and capping it in a 350 mL sterile pet bottle and stored under chilled condition.

Cacao Wine. Figure 4 shows the production of cacao wine following the procedure developed by Adomako et al. (2006). Two levels of degree of brix of sweatings were used in the experiments 13 oBrix and 25 oBrix. The substrates were pasteurized at 63.2 oC for 15 min to destroy and inhibit the growth of undesirable microorganisms.

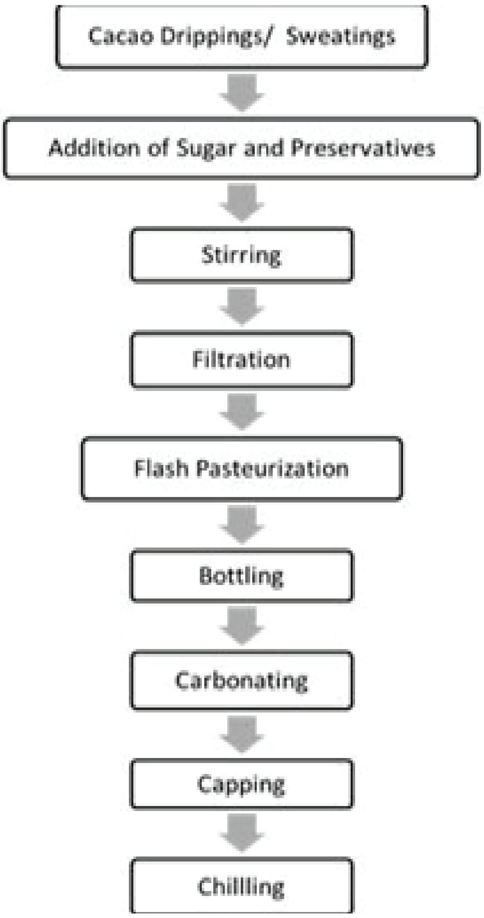


Figure 3. Process flow in the production of cacao health drinks

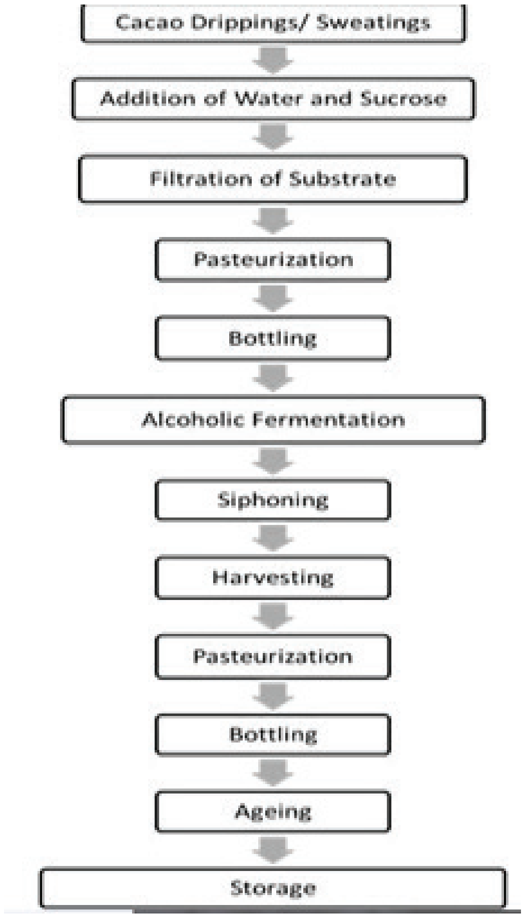


Figure 4. Process flow of the production of cacao wine

One hundred mL of lukewarm pasteurized substrate was added with 0.8 g Saccharomyces cerevisiae at room temperature. Saccharomyces cerevisiae is known as a starter culture in fermentative processes in the production of wine (Rose, 1977; Hansen and Kielland-Brandit, 1996; Demain, 2000; Ostergaard et al. 2000). The starter culture was mixed into a 1 liter substrate at room condition. The substrate was subjected to anaerobic environment for 14 days after adding the starter culture. The process was carried out by capping the bottle with tube and dipped in a container with distilled water to release carbon dioxide.

Alcohol fermentation process was stopped after two to three weeks or after the total soluble solids became constant for three days to allow dead yeast cells and other sediments to settle at the bottom of the container. The coarse wine was decanted by siphoning the clear wine into sterile containers until no sediments were obtained. The clear wine was again pasteurized at 60 °C for 30 min to inhibit the yeast activity and inactivate spoilage microorganisms. The produced wine was cooled to room temperature, and filled to an amber bottle with at least 90% (v/w) of its water capacity and sealed using cork. The filling of the bottle was controlled to meet the headspace requirement of at least 1 inch. The produced cacao wines were stored for two months in a clean, dark and slightly cold cellar room for the aging process.

Cacao Vinegar. Figure 5 shows the process flow of the production of cacao vinegar. The collected cacao wine was pasteurized at 60 °C for 15 min to destroy remaining live yeast.

About 0.80 g of Saccharomyces cerevisiae and unpasteurized mother vinegar were added to cacao wine to start acetic acid fermentation. Fermenting and siphoning process were carried out to make a finer and clearer must. Cacao vinegar was harvested when the 3-5% total titrable acidity of the sample was attained as set by FDA standards.

Physicochemical Properties of Cacao Health Drinks, Wine, and Vinegar

The physicochemical properties of cacao drinks, wine and vinegar were evaluated in terms of pH, total soluble solids (TSS), total titratable acidity, turbidity, density and color and proximate analysis.

Nutritional and Proximate Analysis of Cacao Health Drinks, Wine, and Vinegar

Nutritional analysis for health drinks and proximate analysis of wine and vinegar were conducted at Industrial Technology Development Institute – Department of Science and Technology (ITDI-DOST).

Statistical Analysis

The data gathered was analyzed using simple completely randomized design (CRD). ANOVA table was utilized to determine the level of significant among treatments. The difference between means was compared using Duncan's Multiple Range Test (DMRT).

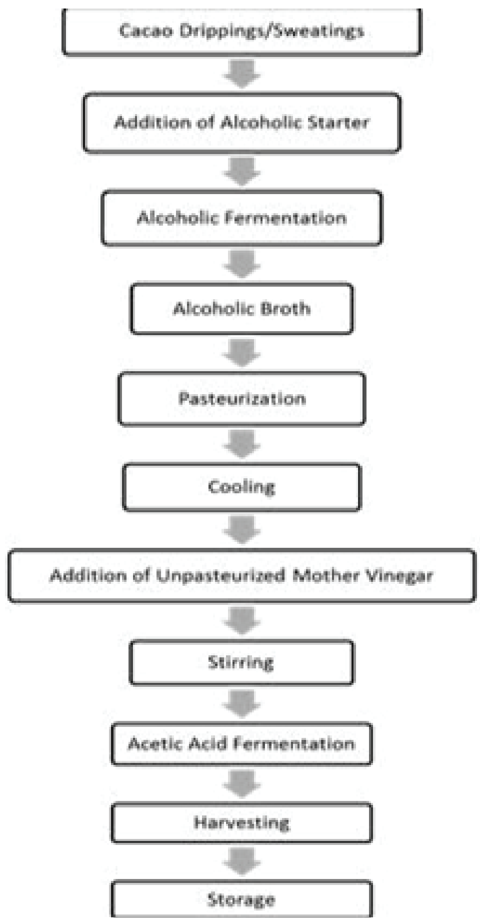


Figure 5. Process flow of the production of cacao vinegar

RESULTS AND DISCUSSION

Description of the Samples

Five clones of cacao were used in the experiment as shown in Table 1. Among the clones, K2 had the highest weight of pods with a value of 778.73 grams, followed by UF18 (679.38 g), UIT(627.39 g), K1(581.77 g) and BR25(342.33). BR25 obtained the highest wet beans recovered with a value of 31.84% followed by UF18 (30.14%), KI(26.71%), UIT(26.57%), and K2(25.94%). While the sweatings obtained ranges from 7.74 to 14.25% of the wet beans. The pulp was approximately 10% of the weight of the cacao fruit (Murugan and Al-Sohaibani 2013) or 15-18% of the wet beans (CDRC 2007).

Extraction of Cacao Sweatings

About 50% of the potential yield of sweating was extracted after four hours of extraction (Table 2). The UF18 had the highest total yield of sweating (862 ml) after 48 hrs of extraction, followed by K2 (772.5 ml), UIT (476 ml), K1 (440 ml), and BR25 (374 ml). This indicates that the initial weight of the wet bean dictates the volume of the sweating.

Table 1. Description of cacao clone samples

Cacao clones	**Weight, g**			**Percent, %**	
	Pods	**Wet Beans**	**Sweatings**	**Wet Beans**	**Sweatings**
BR25	342.33	108.89	15.50	31.84	14.25
KI	603.99	160.97	13.04	26.71	8.26
K2	778.73	193.26	19.55	25.94	10.12
UF18	719.38	216.21	26.42	30.14	12.22
UIT	627.39	164.46	12.73	26.57	7.74

Table 2.Yield of cacao sweating during 48 hrs of extraction

Extraction Time (hr)	**Cacao clones**									
	BR25		**UF18**		**K1**		**K2**		**UIT**	
	Ml	%	ml	%	Ml	%	ml	%	ml	%
0	0	0	0	0	0	0	0	0	0	0
1	122	32.6	316	36.7	150	34.1	212	27.4	148	31.1
2	19	37.7	88	46.9	22	39.1	78	37.5	17	34.7
3	19	42.8	22	49.4	17	42.9	15	39.5	11	37.0
4	7	44.7	15	51.2	3	43.6	11	40.9	2	37.4
24	141	82.4	272	82.7	172	82.7	290	78.4	165	72.1
36	46	94.7	93	93.5	61	96.5	96	90.9	73	87.4
40	14.0	98.4	31.0	97.1	12.0	99.3	40	96.1	21	91.8
48	6.0	100.0	25.0	100.0	3.0	100.0	30.5	100.0	39	100.0
Total	**374**		**862**		**440**		**772.5**		**476**	

Physicochemical Properties of Cacao Sweatings

Table 3 shows the physicochemical properties of cacao sweatings. The newly extracted cacao sweating can be characterized as low acid having an average pH of 4.67 while its total soluble solids is high with an average of 13.5 oBx. According to Morton (1987), Franco (1999), and Alves et al. (2000), high amount of sugars and weak acid has a potential for the production of beverage products such as health drinks, vinegar, wine, ethanol and among others.

Production of Cacao Sweating-based Products

The cacao sweatings was used to optimize the production of health drinks, wine and vinegar.

Cacao Health Drink. The total soluble solids, total titratable acidity and pH were 12 ^{o}Brix, 0.754% and 3.6, respectively (Table 4). The pH value of cacao sweatings was higher than the pH value of orange juice (3.23-3.53) (Esteve et al. 2005).

Nutritional Analysis of Cacao Health Drinks. The nutritional analysis of the cacao health drink was administered by the Standards and Testing Division-ITDI-DOST, Taguig Metro Manila. A 330 mL serving of cacao health drinks contained 156.42 kcal which can provide 6.2% and 8.1% of the required daily energy intake of an adult male and female, respectively. It had also no trace amount of fat and this can be considered "fat-free," "no fat," or "zero fat" drink. Vitamin B1 (thiamin) content of the cacao drink was sufficient enough to provide daily value for men (12.18%) and for women (13.30%). Likewise, the cacao health drinks juice can be considered a good source of potassium and magnesium as it can provide at least 10% DV for both men and women. For sodium content, it can provide 27.46% DV for both men and women. Food is considered a good source of a specific nutrient if the nutritional content is between 10-19%, or a high source if the food provides 20% or more of the required daily intake (USFDA, 2014).

Table 3. Physicochemical properties of cacao sweatings

Parameters	Mean Value
pH	4.67±0.252
Total Soluble Solids (^{o}Brix)	13.5±0.300
Total Titratable Acidity (Tartaric acid %)	0.803±0.053
Total Titratable Acidity (Citric acid %)	0.643±0.043
Density (g/ml)	1.028±0.010

Table 4. Physicochemical properties of health drink

Parameters	Results
Total soluble solids, ^{o}B	12.00
Total titratable acidity,%	0.75
pH	3.67

Microbial Analysis of Cacao Health Drink. The microbial analysis of cacao health drinks showed no presence of Escherichia coli and yeast and molds indicating a safe level of the product for human consumption (Table 6).

Cacao Wine

During alcoholic fermentation, total soluble solids continuously decreased with the number of days of fermentation. The abrupt decrease in total soluble solids for the first 24th hour of samples from 25.00-7.85±0.21 oBrix and 13.15±0.07 to 3.45±0.21 oBrix can be attributed to the conversion and utilization of sugars for the production of alcohol. Aldemita et al. (2013) stated the under anaerobic conditions, the yeast converts the glucose, fructose, and sucrose found in a must into ethanol.

The pH values of control (13 oBx) samples and treated (25 oBx) decreased from from 3.64±0.04 to 3.62±0.05 and from 3.7±0.01 to 3.85±0.01, respectively after 168 hrs. The decrease of pH during the fermentation is in agreement with the study of Aldemita et al. (2013). The production of organic acids from sugars was utilized of the yeast for its growth.

Organic acids such as pyruvic acid are produced during glycolysis, which may be further metabolized into other organic acids such as succinic acid and malic acid in the citric acid cycle, which is then excreted into the must. The citric acid cycles produce carbon dioxide and water, which leads to the formation of carbonic acid, thus decreasing the pH. Similar to the study of Agu et al. (2015), throughout fermentation, pH of the must is within acidic range. Low pH is inhibitory to the growth of spoilage organisms but creates conducive environment for the growth of desirable organisms. The obtained pH value of processed cacao wine was slightly lower on the optimum pH value 4 for a good quality wine (Reddy and Reddy, 2012).

Table 5. Nutritional composition of cacao health drinks

Nutrient	**Amount per serving (330 ml)**	**% Daily Value (Male)***	**% Daily Value (Female)***
Moisture	290.07 ml	11.50	15.00
Ash	0.90 g	N/A	N/A
Protein	0.73	1.02	0.71
Fat	0.00 g	0.00	0.00
Carbohydrates, total	38.28 g	9.50	12.0
Food energy	156.42 kcal	6.20	8.10
Dietary fiber, total	1.41 g	5.62 – 7.03	5.62 – 7.03
Vitamin C	0.04 mg	0.06	0.07
Vitamin B1 (Thiamin)	0.15 mg	12.18	13.30
Iron (Fe)	0.29 mg	2.42	1.04
Sodium (Na)	137.28 mg	27.46	27.46
Potassium (K)	285.45	14.30	14.30
Calcium (Ca)	11.75	1.57	1.57
Magnesium (Mg)	21.02	8.76	10.01

**Based on the Philippine Dietary Reference Intake of 19-29 year old male and female (FNRI, 2015)*

The total titratable acidity of 0.51 to 0.32 and 0.50 to 0.34 were within the normal limits of dry wines. Varakumar et al. (2012) acquired 4.6 to 0.11 in preparation of mango wine using mango peels.

The alcohol content of the samples increasesd over time. This was due to the Saccharomyces cerevisiae which is responsible for fermenting the sugars present in the must. Although, ethanol yield depends on the initial sugar content in the liquid must (Tesevic et al., 2009).

Cacao Wine Recovery. Table 8 shows the percent recovery of cacao wine after 10 days of fermentation. The treated cacao sweating (25 oBx) obtained a high wine recovery (76%) compared to control samples (62.78%). This can be attributed to the high amount of sugar in the samples and the unutilized fermentable sugar.

Proximate Analysis of Cacao Wine. Proximate analysis was conducted for the treated samples which obtained a higher wine recovery as presented in Table 9, the processed cacao wine had an ash content of 0.335%, total acids (0.758%), fixed acids (0.516%), volatile acids (0.242%), specific gravity (0.998), ethyl alcohol (12.6%), and n-Propyl alcohol (12.8%). Likewise, no total aldehydes and iso-butyl alcohol were detected.

Vinegar Production

The physicochemical properties of cacao sweating during alcoholic fermentation stage are summarized in Table 11. The pH, total soluble solids and total titratable acidity were evaluated every 24 hours. The pH of the control and Treatment 2 decreases from 3.37 to 3.35 and 3.38 to 3.26, respectively. The pH value of the samples decreases as the fermentation time increases.

Table 6. Microbial Analysis of Cacao health drink

Sample	Method used	Microbial test	Microbial load (cfu/ml)	Microbial load limit (cfu/ml)
S-2016-01-001A	Serial Dilution	Total count	14	
S-2016-01-001B	Serial Dilution	*E. coli*	<1	<1
S-2016-01-001C	Serial Dilution	Yeast and molds	<1	<1

Table 7. The physicochemical properties of cacao wine

Fermentation Time (Days)	Parameters							
	pH		TSS		TTA		Alcohol Content	
	T1 (Control 13°B)	T2 (25°B)	T1 (Control 13°B)	T2 (25°B)	T1 (Control 13°B)	T2 (25°B)	T1 (Control 13°B)	T2 (25°B)
0	4.67±0.25	4.67±0.25	13.15±0.07	25.00±0.00	0.64±0.04	0.64±0.04	0.00	0.00
24	3.64±0.04	3.7±0.01	13.15±0.07	25.00±0.00	0.51±0.10	0.50±0.08	0.00	0.00
36	3.61±0.02	3.17±0.01	4.70±0.57	11.40±0.71	0.37±0.02	0.35±0.01	4.23^b	6.80^a
72	3.65±0.06	3.78±0.00	4.10±0.14	9.20±0.57	0.40±0.01	0.35±0.01	4.53^b	7.90^a
96	3.66±0.04	3.81±0.04	4.25±0.07	8.30±0.14	0.32±0.01	0.34±0.00	4.45^b	8.35^a
120	3.62±0.01	3.84±0.01	4.20±0.00	7.70±0.42	0.38±0.01	0.38±0.08	4.48^b	8.65^a
144	3.67±0.16	3.72±0.16	4.10±0.00	7.85±0.21	0.38±0.03	0.42±0.00	4.53^b	8.58^a
168	3.62±0.05	3.85±0.01	4.30±0.28	7.00±0.42	0.35±0.01	0.35±0.00	4.43^b	9.00^a
192			4.05±0.07	7.90±0.00	0.36±0.02	0.41±0.01	4.55^b	8.55^a
216			3.70±0.14	7.80±0.14			4.73^b	8.60^a
240			3.45±0.21	7.85±0.21			4.85^b	8.85^a

Table 8. Percent recovery of cacao wine after 10 days

Treatments	Initial Volume, ml	Final Volume, ml	Percent Recovery
Control-13 °Brix	1800	1130	62.78^{b}
Treatment 2-25 °Brix	2250	1710	76.00^{a}

Average or means with the same superscript letters within column indicate no significant difference (p <0. 05)

Table 9. Proximate Analysis of Cacao Wine

Characteristics	Result	Test Method
Ash, %	0.335	920.67
Total Acids (Tartaric acid),%	0.758	945.08A
Fixed Acids, %	0.516	945.08B
Volatile Acids, %	0.242	945.08C
Specific gravity (at 20°C)	0.998	920.56
Total Aldehydes, mg/100mL	0	USP 23, 1993
Ethyl Alcohol, %	12.6	Gas Chromatography
n-Propyl Alcohol, g/100L	12.8	Gas Chromatography
iso-butyl Alcohol, g/100L	ND	Gas Chromatography
iso-Amyl Alcohol, g/100L	8.37	Gas Chromatography
Ethyl Acetate, g/100L	ND	Gas Chromatography

Table 10. Microbial load of Cacao Wine

Sample	Method used	Microbial test	Microbial load (cfu/ml)	Microbial load limit (cfu/ml)
S-2016-01-001A	Serial Dilution	Total count	<1	10
S-2016-01-001B	Serial Dilution	*E. coli*	<1	10
S-2016-01-001C	Serial Dilution	Yeast and molds	<1	10

The total soluble solids of both Treatment 1 and Treatment 2 decreased as the fermentation period increased. This was due to the Saccharomyces cerevisiae converting the sugars into ethanol. The alcohol content was attained after nine days (Treatment 1) and five days (Treatment 2) of fermentation because there is no significant change on the TTA of the samples.

The total titratable acidity (TTA) in alcoholic fermentation had similar results to the wine production. The TTA Treatments were erratic but consistently almost on the same path. This result is in agreement with the work of Jackson (2008) wherein the yeast has metabolized the sugars into ethanol instead of producing organic acids in the citric acid cycles, and thus the change in titratable acidity is very small.

The alcohol content of the samples increased as the fermentation time increased. This was due to the Saccharomyces cerevisiae converting the sugar present in the substrate to ethanol thus an increase in alcohol content. Treatment 2 has higher alcohol content (5.60%) than Treatment 1 (4.65%). This can be attributed to the higher level of sugar of the Treatment 2.

Acetic Acid Fermentation. Table 12 shows the progression of the physicochemical properties such as total soluble solids, pH and total titratable acidity at different stages of the acetic acid fermentation. The total titratable acidity of the samples increases during four months of fermentation h time from 0.811% to 6.77% (T2) and 0.753% to 5.250% (T1). Conversely, the pH of vinegar decreased from 3.28 to 2.99 (T2) and 3.69 to 2.98 (T1), respectively. The FDA legal standard for percent acidity of vinegar is 3-4%.

Proximate Analysis of Cacao Vinegar. Proximate analysis of cacao vinegar presented in Table 13 showed a total solids of 5.79%, ash (0.159%), alkalinity (0.253 ml), non-volatile acids (0.492%), Total titratable acidity (5.36%), total soluble solids (8.29 °Brix), non-volatile reducing substances (3.31%) and permanganate oxidation number (13.1).

Table 11. Physicochemical properties of cacao sweating during alcoholic fermentation

Fermentation Time (Days)	Parameters							
	pH		TSS		TTA		Alcohol Content	
	T1 (Control 13°B)	T2 (25°B)	T1 (Control 13°B)	T2 (25°B)	T1 (Control 13°B)	T2 (25°B)	T1 (Control 13°B)	T2 (25°B)
0	3.37	3.38	13.10	25.00	-	-	0.00	0.00
1	3.36	3.33	4.60	21.60	0.51	0.25	4.25a	1.70b
2	3.49	3.31	3.25	19.20	0.40	0.33	4.69a	2.90b
3	3.46	3.26	3.80	16.30	0.40	0.35	4.65	4.40
4	3.48		3.35	13.90	0.32	0.34	4.57b	5.60a
5	3.48		4.05		0.39		4.53	
6	3.48		4.05		0.40		4.53	
7	3.42		3.75		0.35		4.68	
8	3.35		3.80		0.36		4.65	

Average or means with the same superscript letters within column indicate no significant difference (p <0.05)

Table 12. Physicochemical properties of cacao sweatings in acetic acid fermentation

Fermentation Time (Days)	Parameters					
	TSS, °Brix		pH		TTA, %	
	T1 (Control 13°Brix)	T2 (25°Brix)	T1 (Control 13°Brix)	T2 (25°Brix)	T1 (Control 13°Brix)	T2 (25°Brix)
1	3.85	12.15	3.69	3.28	0.753	0.811
2	3.7	9.25	3.54	3.2	1.068	1.095
3	3.85	9.5	3.27	3.07	3.08	3.613
4	3.65	8.3	2.98	2.99	5.25	6.77

Average or means with the same superscript letters within column indicate no significant difference (p <0.05)

Table 13. Proximate analysis of cacao vinegar

Parameters	Results
Total Solids, %	5.79
Ash, %	0.159
Alkalinity, ml	0.253
Non-Volatile Acids, %	0.492
Total Titratable Acidity, %	5.36
Total Soluble Solids, °Brix	8.295
Non-volatile Reducing Substances (Sugar), %	3.31
Permanganate Oxidation Number	13.1

CONCLUSIONS

The cacao sweatings had an average pH of 4.67, which can be characterized as weak acid while its total soluble solids had an average of 13.5 oBrix that can be used for the production of beverage products such as health drinks, vinegar, wine, ethanol, among others.

Processing of cacao sweatings into wine, vinegar, and health drinks is another way of utilizing the cacao wastes instead of allowing them to flow freely in the fermentary area.

The microbial load (e.g. aerobic plate count, yeast and molds, total viable count, e-coli) of cacao sweating, wine, vinegar and health drinks obtained a value of <1 cfu/ml. This complies to the standard safety level set by USDA.

RECOMMENDATIONS

The shelf life of the health drinks produced should be studied to determine the storability under the Philippine conditions.

Sensory evaluation such as quality descriptive analysis should be done to compare the product produced with commercial products.

The establishment of village-type cacao by-products plant in major cacao producing areas is recommended.

Moreover, the conduct of a study on the economic viability of a village-type cacao by-products plant to enhance the income of cacao growers/processors and at the same time address the problem of waste disposal and environmental pollution is recommended.

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Rodeo, AJ. 2009. Low temperature conditioning to alleviate chilling injury in mango (*Mangifera indica* L. Cv. Carabao fruit (BS Thesis) College, Laguna, Philippines: University of the Philippines Los Banos.

• *Paper from a Proceedings*

M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, “High resolution fiber distributed measurements with coherent OFDR,” in Proc. ECOC’00, 2000, paper 11.3.4, p. 109.

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Scofield, A. Undated. Vietnam: Silent Global Coffee Power. Retrieved on August 4, 2007 at http://www.ineedcoffee.com/02/04/vietnam/

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Agricultural Machinery Testing and Evaluation Center (AMTEC). 2003. Philippine Agricultural Engineering Standards. Volume 1. 2003. PAES 124:2002 Agricultural Machinery – Walking-type Agricultural Tractor – Specifications Part 3: Special Type (Float-Assist Tiller). College, Laguna, Philippines: University of the Philippines Los Banos (UPLB). p.8